Baker & Millspaugh

Experiments to Confirm
The Theory of Stresses
In Chain Links

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EXPERIMENTS TO CONFIRM THE THEORY OF STRESSES IN CHAIN LINKS

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

RAY LUZERNE BAKER and MARTIN LAURENCE MILLSPAUGH

ENTITLED EXPERIMENTS TO CONFIRM THE THEORY

OF STRESSES IN CHAIN LINKS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering

Table of Contents.

References.

1. "An Investigation of the Stresses in Links with Elliptical and Oval Center Lines" by G. A. Goodenough. Thesis for the Degree of Mechanical Engineer, University of Illinois.

2. "Tests of Chain Links" by Mr. R. M. Evans. Thesis for the Degree of Bachelor of Science in Mechanical Engineering, University of Illinois.

Experiments to Confirm the Theory of Stresses in Chain Links.

I. Introduction.

As the uninitiated looks at the ordinary chain, he seldom realizes the difficulties accompanying an analytical investigation of the stresses in each link. Although, at the present day, chains are used constantly in every branch of engineering work, little is known concerning the forces to which they are subjected.

So far as known, there are only three analytical investigations on record. Two are by Germans; Winkler and Grashof, while the third is by Professor G. A. Goodenough of the University of Illinois. In discussing the first named theories, Pro-

fessor Goodenough, who has studied them carefully, makes the following statement: "Both are faulty. Winkler, by making an assumption not justified by fact, underestimates the strength of the links. Grashof, by incorrect reasoning, arrives at results that if adopted would lead to a serious overestimation of the strength of the link." Hence both the Winkler and Grashof theories are of little practical value.

In a thesis for the degree of Mechanical Engineer, presented in June, 1900, Professor Goodenough gives an elaborate analytical investigation of the stresses in chain links of different sizes and shapes. The fundamental theory underlying these investigations is contained in Bach's "Elasticitat und Festigkeit". Professor Goodenough extended this analysis

to links with elliptical center lines; links with straight sides; links with stud; links of lemniscate form; and links with center lines of four and six circular arcs, making circular center lines a special case.

All the theoretical equations of the improved Bach theory used in the following pages were obtained from Professor Goodenough's thesis: reference to which may be had by consulting the University of Illinois library. The ordinary theory used herewith is that usually employed in modern practice

As a thesis for the degree of Bachelor of Science in Mechanical Engineering in June 1906, Mr. R. M. Evans conducted a series of tests upon several sets of commercial chain links. These tests were made with the intention of proving or disproving the fundamental

assumptions of Professor Goodenough's improved Bach theory. The limited amount of time, however, prevented Mr. Evans from doing little besides the actual testing of the links.

II Object

The object of this thesis is three-fold:

1. The investigation of the reliability of the improved Bach theory for chain links, by means of certain experiments upon links with various center lines.

2. The application of the ordinary theory now in use to this same experimental data.

3. The comparison of the results of the Bach theory with those of the Ordinary theory.

III. Description of Tests.

Both the Bach and ordinary theories permit of an estimation of the probable deformation of the links as a chain is placed under tension. These deformations may also be actually measured by means of a simple mechanical device, when the link is pulled in an ordinary tension machine. The theoretical and actual deformations may then be plotted and a comparison made between them. If the two agree, it can be assumed that the fundamental assumptions of the theoretical analysis are correct. Since the theory holds equally well for special links and rings, for which the computations are more simple than for the ordinary elliptical link, it was decided to test several of

Fig. I.

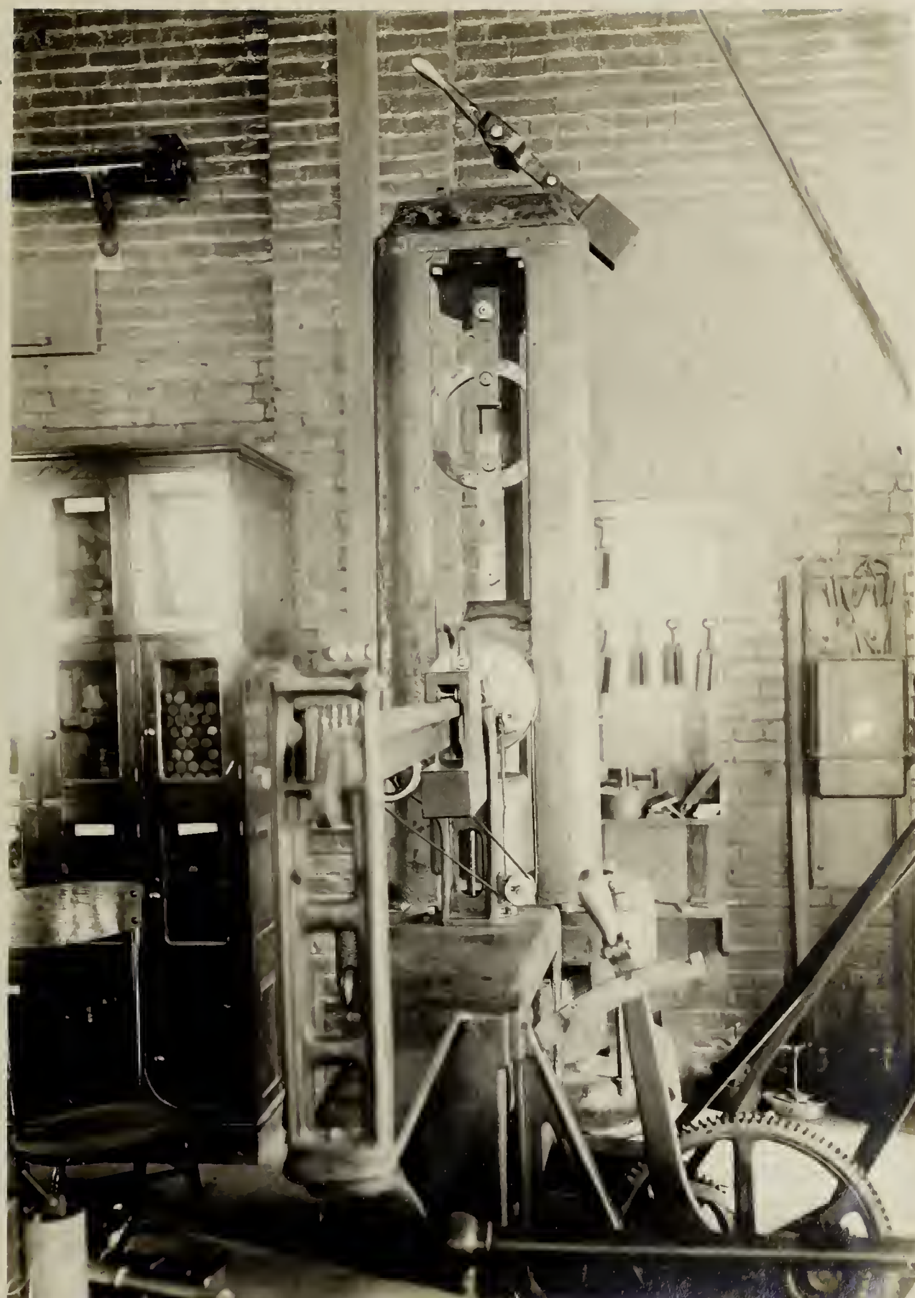


Fig. II.

Fig. III.

these, of different sizes, within the elastic limit of the material. In addition to the above, results of some of the tests made by Mr. Evans were also used for this purpose.

Figures I. and II. show the method of pulling the rings. As may be seen, the pulling fixture consists of straps, connected on one end to the block that is placed in the machine jaws and carrying on the other end the knife edge that supports the ring. Care was taken to get right angle motion in the fixture to insure against binding or complicated stresses in the rings. The right angle pivot-joint used accomplished this purpose very nicely and therefore the rings were subjected to a good straight pull.

Figure III. shows the method of testing the chain links. In this

case a rigid bar was brazed to each end of the middle link in the manner shown in the cut. As the links were loaded, deflections were measured between the opposite contact points on these bars by means of an inside micrometer caliper. The deflections of the other axis were measured directly. To obviate certain errors which were liable to occur in making readings, two independent tests were made on each ring and chain link. In the first, called the preliminary test, the loads were gradually applied in increments varying with the size and capacity of the ring or link and the deflections of each axis carefully measured by means of large micrometers which read to one ten-thousandth of an inch. Care was taken not to exceed the elastic limit of the material

before the check test was run. In order to determine the probable deformations of any link, it is necessary to know the modulus of elasticity of the material of which the link is made. Hence, a standard test piece was furnished with each set of test rings and links. These pieces were tested in the usual manner for obtaining the properties of the material.

It might also be mentioned in this connection that not all of the tests made proved satisfactory for various reasons. This is true of the 9-inch rings, numbers 4. and 5. and the 1-inch chain, sample number 9. The rings were excluded from the final data because it was found that the hot drawing had brought certain internal stresses which were detrimental to the purpose for which the data was taken. In the case of

the 1 [illegible] inch chain the test was lost through the poor design of the measuring device. An attempt was made to measure the deflections by means of inside micrometers and electric bell contact. The results were a failure and while the readings were being taken, the elastic limit of the material was exceeded, the link consequently being spoiled. After the laboratory testing had been completed, curves were plotted showing the deflections of each axis for the different applied loads. The results of both the preliminary and check tests were treated in this manner. These curves, as will be seen later, become very useful in showing the coincidence of theory and practice.

IV. Analysis - Stresses and Deflections.

Nomenclature.

See Figure 1., and Plate II.

P = Normal force at any section, in pounds.

Q = One half the applied load on link, in pounds.

M = moment at sections along minoi axis

$d\varphi$ = The variable angle between the major and minor axis. $d\varphi$ varies from, $(0 \text{ to } \alpha)$, $(\alpha \text{ to } \beta)$, and from $(\beta \text{ to } \pi/2.)$

r = Radius of curvature at section in question, in inches.

d = Diameter of the stock of the link, in inches.

b = One half the minor axis of link, in inches

K = The quantity, $\alpha + \sin\alpha \cos\alpha$.

l = Perpendicular distance between the first and second centers of curvature, in inches

a = $l + d$.

i = Perpendicular distance between the intersection of the center line of the link, with the major axis and the second center of curvature, in inches.

h = Perpendicular distance between the intersection of the center line of the link with the minor axis and the second center of curvature, in inches.

Δa = Lengthening of major axis of link, in inches

Δb = Shortening of minor axis of link, in inches.

f = Area of cross section of link, in square inches.

E = Modulus of elasticity of material of link.

$\mathcal{H}$ = A function analogous to the moment of inertia of cross section. The series giving the value of $\mathcal{H}$ varies for different shaped sections.

a. For circular sections

$$\frac{1}{\mathcal{K}} = 4\left(\frac{r}{\rho}\right)^2 - 2 - \frac{1}{4}\left(\frac{\rho}{r}\right)^2.$$

b. For rectangular sections-

$\frac{1}{\mathcal{K}} = 3\left(\frac{\rho}{a}\right)^2 + 5\left(\frac{\rho}{a}\right)^4$, – when "a" equals half the width of the section; ρ = radius of curvature at section under consideration, and r = $\frac{1}{2}$ Diameter of the stock of the link.

s = h - b. In inches } Used only in ordinary theory.
p = r_3 - b. " " }

I = Moment of inertia for section under consideration.

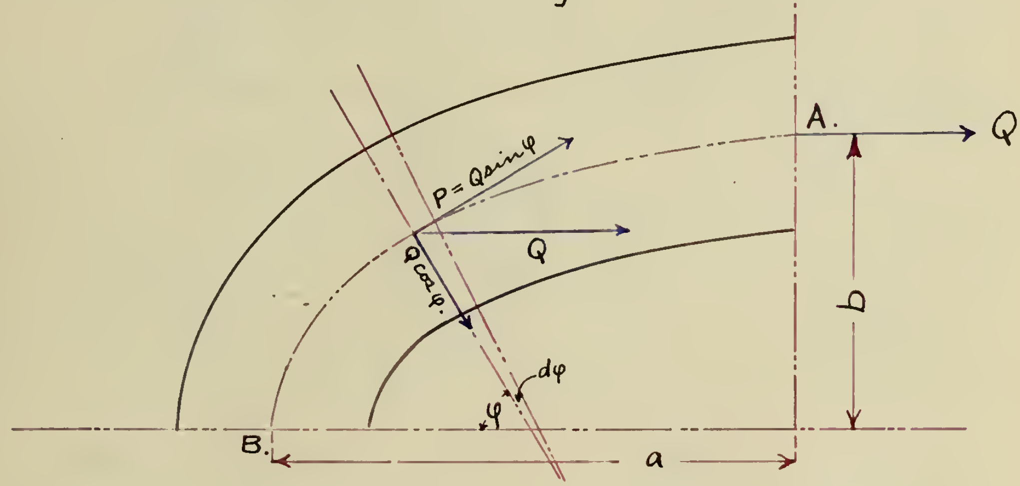
e = Perpendicular distant between third center of curvature and minor axis of link, in inches.

Formulae.

The following comprise some of the principal formulae used in this thesis. Their derivation may be found in Professor Goodenough's discussion:

1. Bach Theory.

Fig.1.



A. For links with center lines composed of six circular arcs, load assumed to be distributed.

At any section under question,- (See figure 1.)

a. Value of M.

$$M = -Qd\left[\frac{\frac{b}{d}\left(1+\frac{1}{\kappa_1}\right)\alpha+\left(1+\frac{1}{\kappa_2}\right)(\beta-\alpha)+\left(1+\frac{1}{\kappa_3}\right)\left(\frac{\pi}{2}-\beta\right)-\frac{1}{\kappa_2}(\cos\alpha-\cos\beta)-\frac{1}{\kappa_3}\cos\beta-\frac{1}{\kappa_1}\left(\frac{2\sin\alpha}{K}-\cos\alpha\right)}{\alpha\left(1+\frac{1}{\kappa_1}\right)+\frac{d}{r_2}\left(1+\frac{1}{\kappa_2}\right)(\beta-\alpha)+\frac{d}{r_3}\left(1+\frac{1}{\kappa_3}\right)\left(\frac{\pi}{2}-\beta\right)+16\frac{e}{d^2}}\right]$$

b. Deformation of major axis.-

$$E f\cdot \Delta a = -(M+Qb)\frac{1}{\mathcal{H}_1}(1-\cos\alpha) + \frac{Qd}{4K\mathcal{H}_1}\left(2\sin^4\alpha + \alpha^2 - 2\alpha\sin\alpha\cos\alpha + \sin^2\alpha\right)$$
$$-(M+Qh)\frac{1}{\mathcal{H}_2}(\cos\alpha - \cos\beta) + \frac{Qr_2}{4\mathcal{H}_2}(\beta-\alpha+\sin\alpha\cos\alpha - \sin\beta\cos\beta)$$
$$+(M+Qh)\frac{1}{r_2}(h-b)\left(1+\frac{1}{\mathcal{H}_2}\right)(\beta-\alpha) - Q(h-b)\frac{1}{\mathcal{H}_2}(\cos\alpha-\cos\beta)$$
$$-(M+Qr_3)\frac{\cos\beta}{\mathcal{H}_3} + \frac{Qr_3}{2\mathcal{H}_3}\left(\frac{\pi}{2}-\beta+\sin\beta\cos\beta\right)$$
$$+(M+Qr_3)\frac{r_3-b}{r_3}\left(1+\frac{1}{\mathcal{H}_3}\right)\left(\frac{\pi}{2}-\beta\right) - (r_3-b)\frac{Q}{\mathcal{H}_3}\cos\beta - 16\frac{be}{d^2}M.$$

c. Deformation of minor axis.-

$$-Ef\Delta b = \alpha\frac{l}{d}(M+Qb)\left(1+\frac{1}{\mathcal{H}_1}\right) + (M+Qb)\frac{\sin\alpha}{\mathcal{H}_1} - \frac{Ql}{\mathcal{H}_1}\left(\frac{2\sin\alpha}{K} - \cos\alpha\right)$$
$$-\frac{Qd}{4\mathcal{H}_1}(2\sin^2\alpha+1) + \frac{Qd}{2K\mathcal{H}_1}\alpha\cos^2\alpha + \left(\frac{a-i}{r_2}\right)(M+QH)\left(1+\frac{1}{\mathcal{H}_2}\right)(\beta-\alpha)$$
$$+(M+QH)\frac{1}{\mathcal{H}_2}(\sin\beta-\sin\alpha) - Q\left(\frac{a-i}{\mathcal{H}_2}\right)(\cos\alpha-\cos\beta) - \frac{Qr_2}{2\mathcal{H}_2}(\sin^2\beta-\sin^2\alpha)$$
$$+\frac{M+Qr_3}{\mathcal{H}_3}(1-\sin\beta) - \frac{Qr_3}{2\mathcal{H}_3}(1-\sin^2\beta) + 8M\frac{e^2}{d^2}.$$

B. For links of circular lines; load concentrated.

a. Value of M.-

$$M = Qd\left[\frac{2}{\pi(1-\mathcal{H})} - 1\right].$$

b. Deformation of major axis.-

$$Ef\,\Delta a = -\frac{1}{\mathcal{H}}(M+Qr) + \frac{\pi}{4}\frac{Qr}{\mathcal{H}}.$$

c. Deformation of minor axis.-

$$E\cdot f\cdot \Delta b = (M+Qr)\left(1+\frac{1}{\mathcal{H}}\right)\left(\frac{\pi}{2}-1\right) - \frac{Qr}{2\mathcal{H}}.$$

2. Ordinary Theory.

A. For links with centerlines composed of six circular arcs, load assumed to be distributed.

a. Value of M.-

$$M = Q\left[\frac{-bd\alpha - hr_2(\beta-\alpha) + r_2^2(\cos\alpha-\cos\beta) - r_3^2\left(\frac{\pi}{2}-\beta\right) + r_3^2\cos\beta - d^2\cos\alpha + 2d^2\frac{\sin\alpha}{K}}{\alpha d + r_2(\beta-\alpha) + r_3\left(\frac{\pi}{2}-\beta\right) + e}\right]$$

b. Deformation of major axis. –

$$
\begin{aligned}
E_f\,\Delta a =\ & \frac{Q r_2}{2}\left(\beta-\alpha-\sin\beta\cos\beta+\sin\alpha\cos\alpha\right)+\frac{Q r_3}{2}\left(\frac{\pi}{2}-\beta+\sin\beta\cos\beta\right) \\
& -16(M+Qb)(1-\cos\alpha)+\frac{17}{4}\frac{Qd}{K}\left(2\sin^4\alpha+\alpha^2-\alpha\sin\alpha\cos\alpha+\sin^2\alpha\right) \\
& -16(M+Qh)\frac{r_2^2}{d^2}(\cos\alpha-\cos\beta)+16(M+Qh)\frac{s r_2}{d^2}(\beta-\alpha) \\
& +\frac{8Qr_2^3}{d^2}\left(\beta-\alpha-\sin\beta\cos\beta+\sin\alpha\cos\alpha\right)-16\frac{Qs r_2^2}{d^2}(\cos\alpha-\cos\beta) \\
& -16(M+Qr_3)\frac{r_3^2}{d^2}\cos\beta+16(M+Qr_3)\frac{p r_3}{d^2}\left(\frac{\pi}{2}-\beta\right) \\
& +\frac{8Qr_3^3}{d^2}\left(\frac{\pi}{2}-\beta+\sin\beta\cos\beta\right)-\frac{16Qr_3^2p}{d^2}\cos\beta-16\frac{Mbe}{d^2}+Qe
\end{aligned}
$$

c. Deformation of minor axis. –

$$
\begin{aligned}
E_f\,\Delta b =\ & 16(M+Qb)(\alpha-\sin\alpha)+\frac{17}{4}\frac{Qd}{K}\left(\alpha\,2\sin^2\alpha-\alpha+\sin\alpha\cos\alpha\right)+\frac{Qr_3\cos^2\beta}{2} \\
& -\frac{16Qd}{K}\left(\sin^3\alpha+\sin\alpha-\alpha\cos\alpha\right)+\frac{17}{2}Qd\sin^2\alpha+16(M+Qh)\frac{i r_2}{d^2}(\beta-\alpha)+\frac{8Qr_3^3\cos^2\beta}{d^2} \\
& -16(M+Qh)\frac{r_2^2}{d^2}(\sin\beta-\sin\alpha)-16\frac{Qi r_2^2}{d^2}(\cos\alpha-\cos\beta)+\frac{8Qr_2^3}{d^2}\left(\sin^2\beta-\sin^2\alpha\right) \\
& +16(M+Qr_3)\frac{a r_3}{d^2}\left(\frac{\pi}{2}-\beta\right)-16(M+Qr_3)\frac{r_3^2}{d^2}(1-\sin\beta)-\frac{16Qr_3^2a}{d^2}\cos\beta+8M\left(\frac{2ae+e^2}{d^2}\right)+\frac{Qr_2}{2}\left(\sin^2\beta-\sin^2\alpha\right)
\end{aligned}
$$

B. For links of circular line, load concentrated

a. Value of M. –

$$M = Qr\left[\frac{2-\pi}{2}\right].$$

b. Deformation of major axis. –

$$\Delta a = \frac{Qr^3}{EI}\left[\frac{\pi}{4}-\frac{2}{\pi}\right]+\frac{rQ}{E_f}\frac{\pi}{4}.$$

c. Deformation of minor axis. –

$$\Delta b = \frac{Qr^3}{EI}\left[\frac{1}{2}-\frac{2}{\pi}\right]+\frac{Qr}{2E_f}.$$

5. Comparison of Bach and Ordinary Theory.

The essential difference between the Bach and Ordinary theory is in the fundamental application of the involved facts. This difference may be explained by reference to the following discussion.

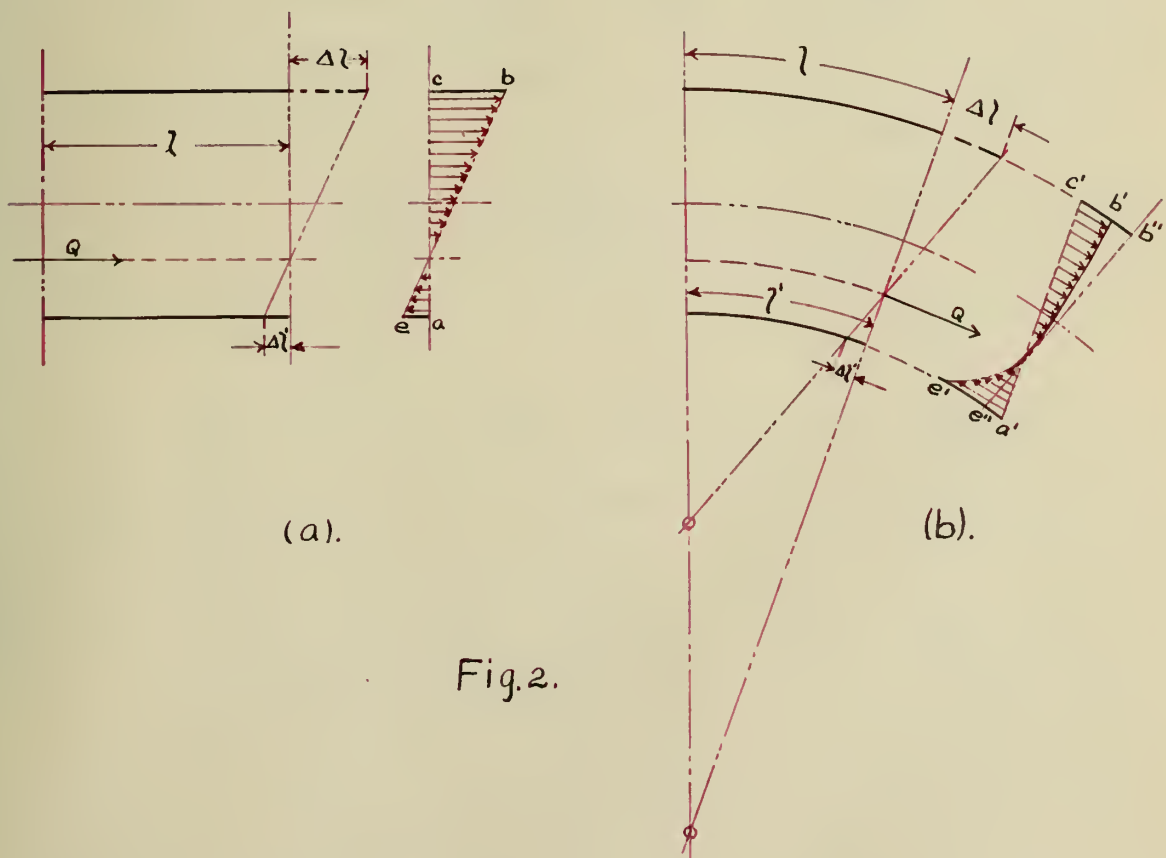


Fig.2.

Considering the sections shown (a), a part of a straight beam eccentric-

ally loaded, and (b) a similar portion of a curved beam, it will be seen that stresses will be set up in the fibers in a manner similar to the stress diagrams shown. In the straight section the stress in the outer fiber is proportional to $\frac{\Delta l}{l}$ while at the inner fiber it is $\frac{\Delta l'}{l}$ or since l is constant the stress in any fiber is proportional to the elongation. The variation of these fiber stresses from compression in the outer fibers to tension in the inner may therefore be represented graphically by the ordinates to the straight line.

In figure 2 (b), however, it is noticed that the same relation will not hold. Since the section is wedge shape the outer fiber for the section is longer than the inner and the stresses will vary somewhat as shown by the curve b'c', similar to the previous case. This gives a much greater tension in the in-

ner fiber than before. Now if the ordinary theory be applied to this case it will indicate that the stresses vary somewhat as given by the straight line b"c". It is now evident that the ordinary theory does not take account of the change in bending moment in a curved section different from that of the straight section. The ordinary theory assumes that the bending moments are the same in both cases. Although this may approximate results in the case of a link with large radius of curvature, there is apt to be a very large error where the radius of curvature is small.

V. Discussion of Results.

The results, as far as the experimental part of this work is concerned, are fairly uniform and satisfactory. This may be seen by referring to the curve sheets, showing deformations. In the case of the large rings, some little difficulty was experienced in getting so large a micrometer accurate enough to read the slight deformations occasioned by the increment loads, without a large percentage of error. The irregularity of the deformations at the beginning of the test where the differences were very small is doubtless due in a large measure to this source. Then, too, it must be remembered that the abscissa of the curves are so selected that each small division of the coordinate paper shows a deflection of only two ten-thousandths of an

inch, and therefore a slight variation from the average is greatly exaggerated by the curves.

As has been seen from the review of the formula given, the computations are involved and laborious. The results of analytical work depend on very accurate computations; in fact, a very slight error in any one part of a given formula will result in a deflection quite contrary to what might be expected. Every precaution was taken and checks were made to make sure that the numerical work was absolutely correct before a comparison between the theoretical and the actual results was attempted. Notwithstanding the care taken, there is likely to be a slight percentage of error in the results; especially in the case of the chain links, since each link

is separately forged and there is a mere chance of the two connecting links making perfect contact, through the particular arc as estimated on the drawn link. Slight irregularities due to forging may distribute the load in a different way than expected and therefore affect the deformations of two similar tests in such a way that the results will not absolutely agree.

The comparison of the various results obtained by theory with those obtained experimentally lead to some very peculiar and interesting information; and since these results vary somewhat for the rings and links, they will be considered separately and the agreement or variance of theory and practice noted in each case. Tests were first made on several large rings and it was found

that the theoretical results agreed very closely with the experimental work. The rings therefore proved very satisfactory in confirming the accuracy of the theory but they were useless when it came to showing any material difference between the ordinary and the improved Bach theory, the two agreeing very closely. The results of the investigation seem to indicate in every case that the theoretical deflections of the major axis are slightly in excess of the actual deflections, while in the case of the minor axis the reverse is true.

It is in connection with the chain links that the real superiority of the improved theory over the ordinary theory is evident. This is to be expected since the fundamental principles underlying the derivation of the improved theory are so

assumed as to take into account the change in curvature as the link is loaded. It will be remembered that the radius of curvature of the rings is relatively large while the radius of curvature of the sections of the ordinary chain link near the ends, becomes quite small. Here, as in the case of the rings, it is found that the improved theory gives very close approximations to the actual results determined by tests, while the ordinary theory is shown to be very much in error. The amount of error varies with the curvature of the section as explained before. This, in a measure, accounts for the major axis comparing more closely to actual tests than the minor axis, since the curvature is sharpest near the ends of the link.

VI. Conclusion.

In view of the experimental data at hand, and the theoretical results obtained, it is evident that the fundamental assumptions of Professor Goodenough's improved Bach theory are substantially correct. The various formulae, therefore, of the improved theory which permit of an estimation of the probable deformations of the link, of a calculation of the maximum stresses in each fiber, and a determination of the safe working load for any given chain, may be applied to actual practice with good results. It would seem that in cases of large radius of curvature, the same might be said of the ordinary theory. For example, where the ratio of diameter of stock, to radius of curvature is

less than $\frac{1}{5}$, as in the case of the test rings (sighted cited) above, still for even these cases the ordinary theory is no simpler than the improved Bach analysis, and the latter gives slightly more uniform results with a closer approximation to the actual test data. With reference to the chain links, where the ratio of diameter of stock to radius of link is generally as high as $\frac{1}{2}$, the ordinary theory is much at fault and gives results that can not be relied upon to any great extent. A comparison of the various curves shows that the deflections are really much less in the actual tests than the ordinary theory indicates.

Not much can be said concerning the variation of stresses in each case, but judging from the computations made

by Professor Goodenough in his discussion of this subject it seems fair to predict that the stresses are really greater in some cases at least than the ordinary theory indicates. It is probable then, that the stresses in the chain become excessive when used with loads equal to those for which it was designed and, therefore, the chain may break and the fault be attributed to other causes than the real one, simply through ignorance of this fact. This may be more emphatically shown by referring to certain rational formula of common usage.

1. <u>According</u> <u>to</u> <u>Weisbach</u>,

$$P = 13,350\, d^2 \, \#.$$

Where P = safe load on chain and,

d = The diameter of stock in inches

2. <u>According to Bach.</u>

$$P = 13,750 d^2 \text{ to } 11000 d^2 \#$$

3. <u>According to Unwin.</u>

$$P = 11,200 d^2 \#$$

4. <u>According to the Improved Theory.</u>

$$P = 6,000 d^2 \#$$

Here also, reference to the actual tests indicates that the real safe load lies in between the improved and Unwin formula, but the improved is the safer and consequently more reliable. It seems reasonable, therefore to expect that the improved Bach theory, as developed by Professor Goodenough, will eventually come into general usage.

VII. Source of Experimental Material.

The material for the test work was variable in its nature and was furnished from widely different sources. The rings number 1 and 2 were steel castings. These were furnished in the rough together with the test pieces by the Milwaukee Steel Casting Company of Milwaukee. Ring number 3 was a forged soft steel ring furnished in the rough through the courtesy of the Big Four Railroad shops of Urbana. Rings number 4, and 5 were made by cutting sections from a nine inch hot drawn steel tube, made by the Western Tube Company. The rings were cut from the rough pipe by the University machine shop. The chains tested were furnished by the Newhall Chain

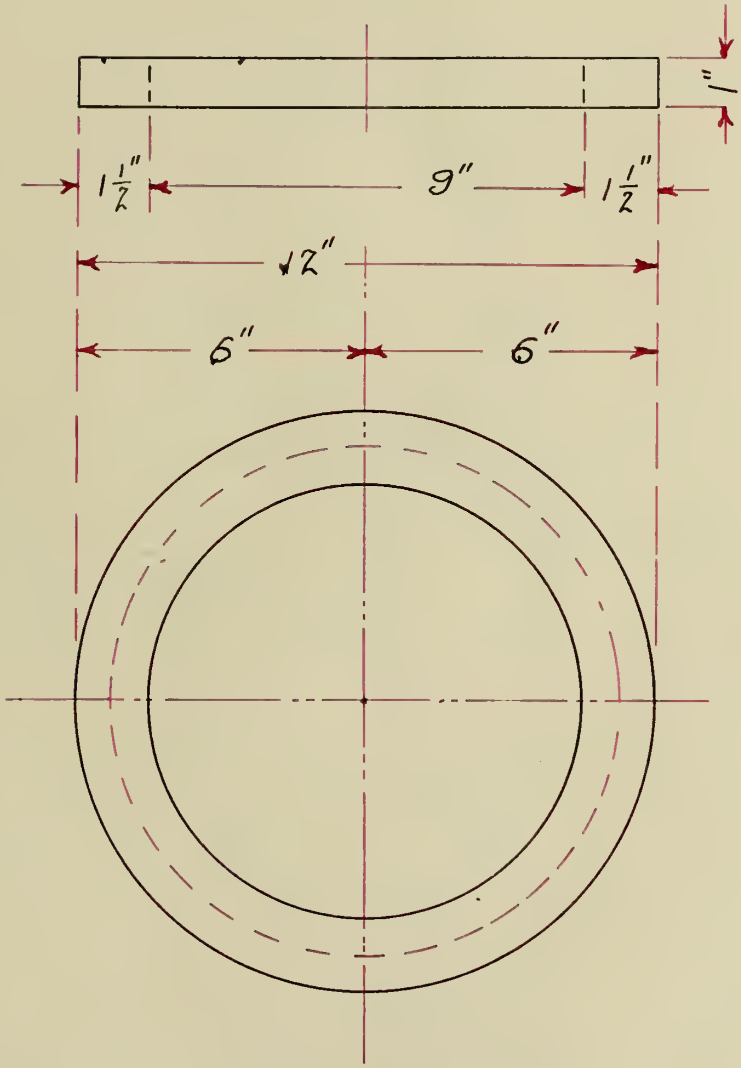
Forge and Iron Company of New York. They consisted of samples of the best grade of dredge and conveyor chains of different sizes. All of the above rings and test pieces were finished at the University machine shop.

It might be well to add that all the material used in making these tests was bought by the Engineering Experiment Station and credit is therefore due this department for making the investigations possible.

VIII. REFERENCE CHART FOR TEST DATA.

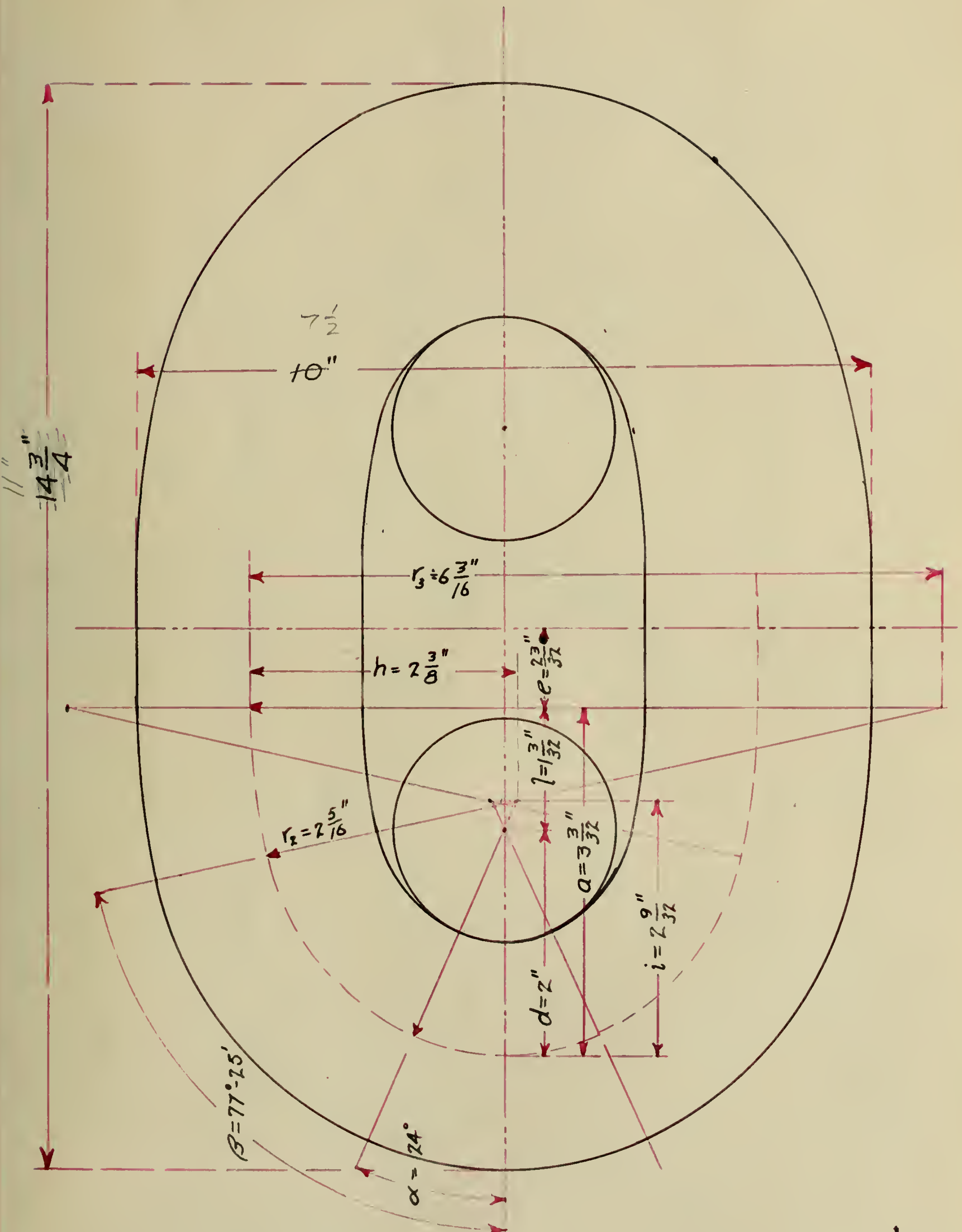
Sample No.	Made By	Material	Link	Curves		
				Properties	Deformations Major	Minor
1	Milwaukee Steel Casting Co.	Steel Casting	Ring	1	2	3
2	"	" "	"	"	4	5
3	Big Four Co.-U-	Bar Iron Steel	"	6	7	8
4	Western Tube Co.	Soft Steel.	"	——	——	——
5	" " " "	" "	"	——	——	——
6	Newhall, Chain, Forge, & Iron Co.	Iron (B.B.)	Dredge	——	9	10
7	"	"	Conveyor	——	11	12
8	Jones & Laughlin Co.	Iron	Dredge	——	13	14

PLATE I



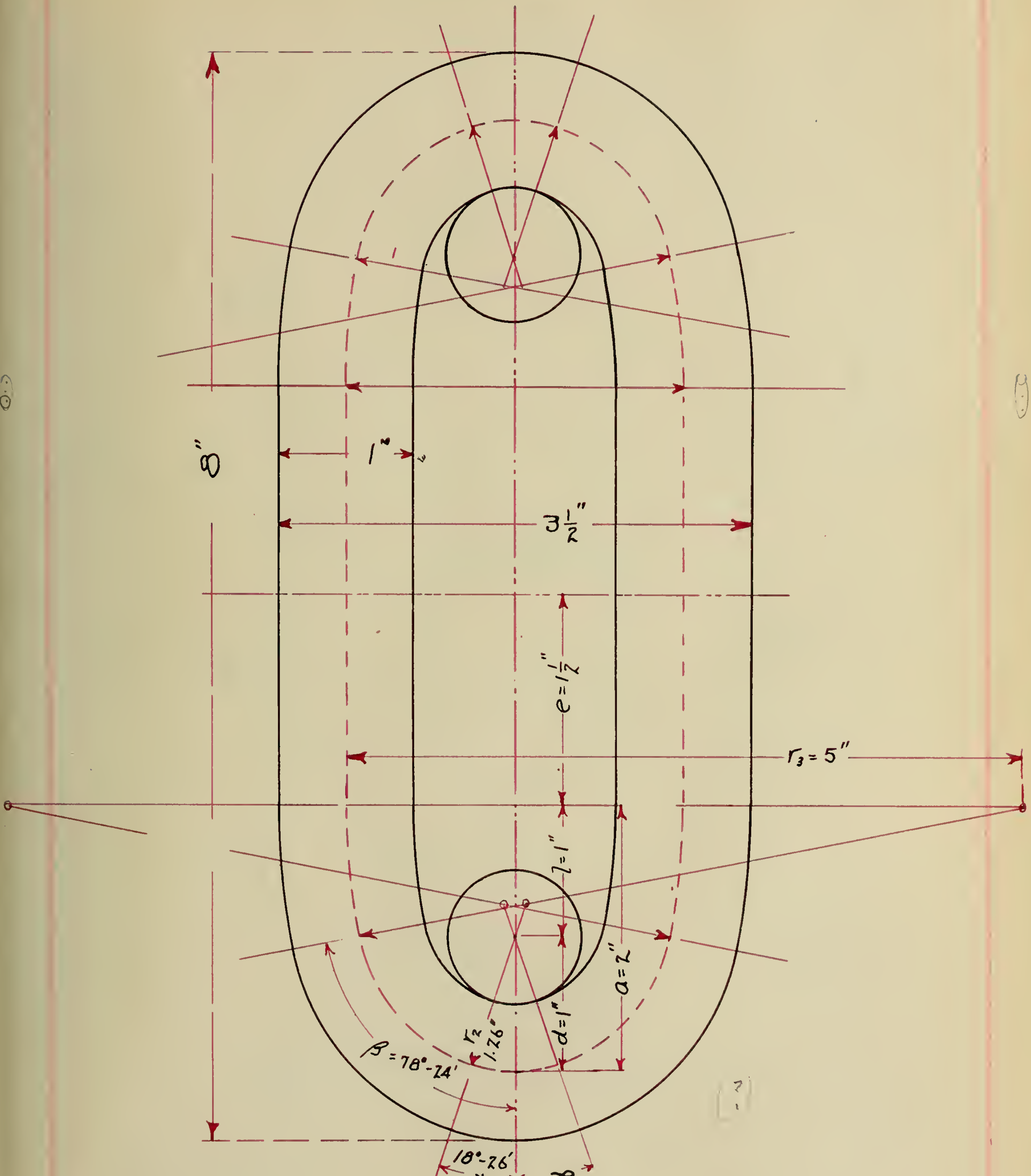
12" RING

PLATE II



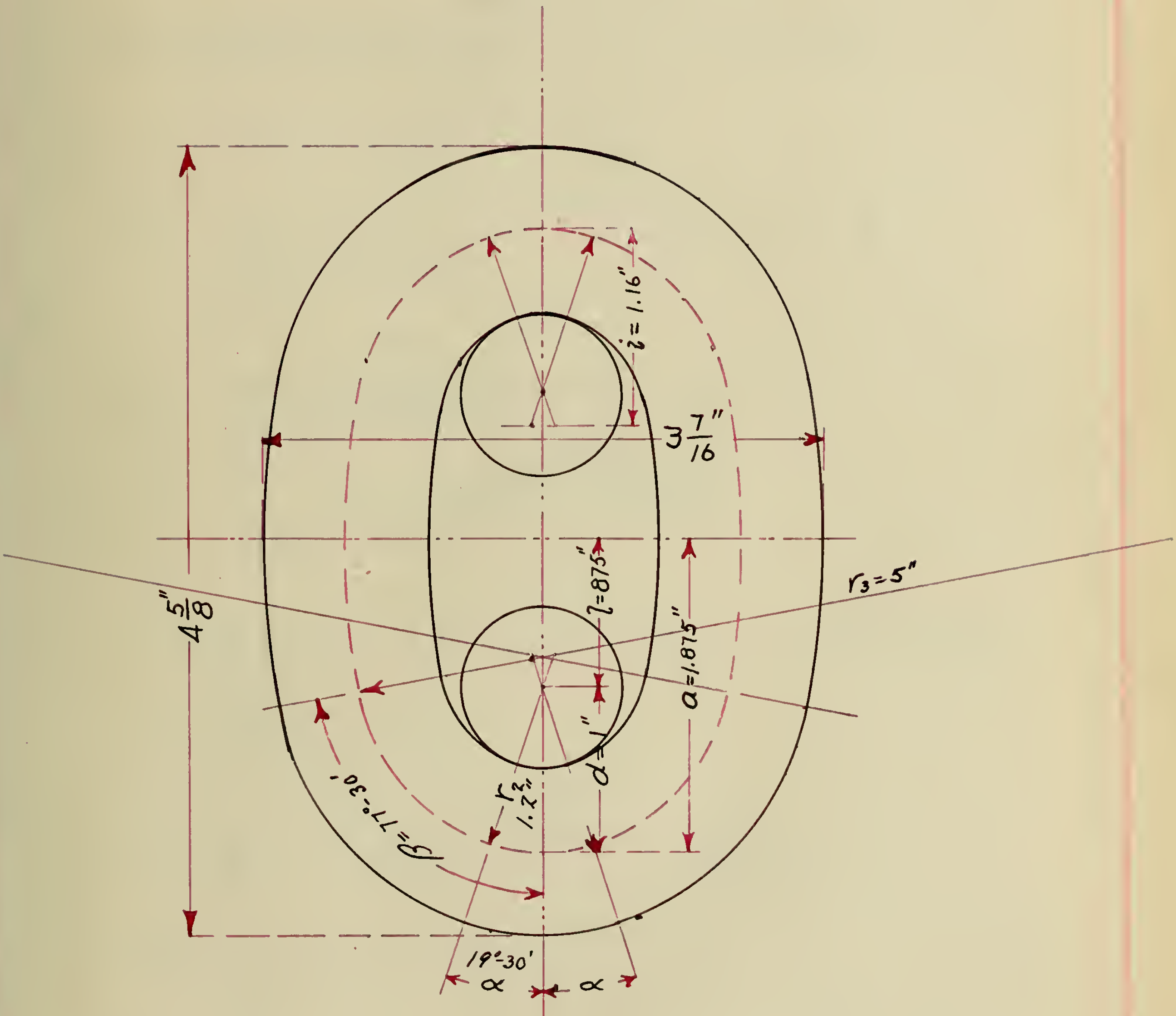
#6 – 2" DREDGE CHAIN

PLATE III



#7 – 2"-CONVEYOR CHAIN

Plate IV



#8 – 1"–Dredge Chain

Ring No 1. [S.C.].

Improved Bach Theory.

$r = 5.25''$ $\qquad b = 1.047''$ $\qquad \frac{1}{86,} = 145.15239$

$a = 0.75''$ $\qquad f = 1.570^{\square''}$ $\qquad E = 26,200,000.$

$I = 0.29447$

$$M = Q\left[\frac{5.25 \times 2}{1.00689 \times 3.14159} - 1\right] = -1.93064\,Q$$

Major Axis-

$$\Delta a = \frac{116.70036}{26,200,000 \times 1.570}\,Q = 0.00000286\,Q$$

Minor Axis-

$$\Delta b = \frac{19.83159 \times 5.25}{26,200,000 \times 1.570}\,Q = -0.00000255\,Q$$

Ordinary Theory.

Major Axis-

$$\Delta a = \frac{Q}{E}\left[73.11314 + 2.64229\right] = 0.00000289\,Q$$

Minor Axis-

$$\Delta b = \frac{Q}{E}\left[\frac{144.7031 \times (-.1366)}{.2945} + \frac{5.25}{2 \times 1.570}\right]$$

$$\Delta b = -0.000002497\,Q$$

Ring No. 2. [S.C.].

Improved Bach Theory.

$r = 5.2514''$ $\quad b = 1.005''$ $\quad \frac{1}{\mathcal{H}} = 145.15239$

$a = 0.7514''$ $\quad f = 1.5131^{\square''}$ $\quad E = 26,200,000.$

$I = 0.28424$

$M = -1.93064\,Q$

Major Axis-

$$\Delta a = Q\left[\frac{116.7036}{26,200,000 \times 1.5131}\right] = 0.00000294\,Q$$

Minor Axis-

$$\Delta b = Q\left[\frac{104.11585}{39,643,953.6}\right] = -0.00000263\,Q$$

Ordinary Theory.

Major Axis-

$$\Delta a = \frac{Q}{E}\left[75.8022 + 2.7258\right] = 0.000002996\,Q$$

Minor Axis-

$$\Delta b = \frac{Q}{E}\left[509.4235 \times (-.1366) + \frac{3.4706}{2}\right]$$

$$\Delta b = -0.000002595\,Q$$

Ring No 3. [W.I.]

Improved Bach Theory.

$r = 5.2595''$ $\qquad b = 1.00''$ $\qquad \frac{1}{\delta 6} = 147.7743$

$a = 0.744''$ $\qquad f = 1.488\,\square''$ $\qquad E = 30,400,000.$

$I = 0.27455$

$$M = Q\left[\frac{5.2595 \times 2}{1.00677 \times 3.14159} - 1\right] = -1.9337\,Q$$

Major Axis -

$$\Delta a = Q\left[\frac{22.5383 \times 5.2596}{30,400,000 \times 1.488}\right] = 0.00000261\,Q$$

Minor Axis -

$$\Delta b = Q\left[\frac{20.5490 \times 5.2596}{30,400,000 \times 1.488}\right] = -0.00000238\,Q$$

Ordinary Theory.

Major Axis -

$$\Delta a = \frac{Q}{E}\left[\frac{145.49 \times .1488}{.27455} + \frac{5.2596 \times .78539}{1.488}\right]$$

$$\Delta a = 0.00000268\,Q$$

Minor Axis -

$$\Delta b = \left[529.9217(-.1366) + \frac{3.53461}{2}\right]\frac{Q}{E}$$

$$\Delta b = -0.00000232\,Q$$

Dredge Chain No. 6.

Bach Theory.

Calculations for the value of M.

$r_1 = 2.$	$r_2^2 = 5.34766$	$\beta = 77°25'$
$r_2 = 2.3125$	$d = 2.$	$\beta = 1.35117\ R$
$r_3 = 6.1875$	$\alpha = 24°$	$\cos\beta = .2179$
$i = 2.28125$	$\tan\alpha = .4452$	$\sin\beta = .9760$
$h = 2.3750$	$\alpha = .41881\ R$	$\sin\beta\cos\beta = .21267$
$b = 2.2813$	$\sin\alpha = .4067$	$\beta - \alpha = .93236$
$a = 3.09375$	$\cos\alpha = .9135$	$\frac{\pi}{2} - \beta = .21962$
$e = .71875$	$K = .79033$	$\cos\alpha - \cos\beta = .6956$
$\sin^2\alpha = .1654$	$\sin^2\beta = .9526$	$\frac{1}{\mathfrak{K}_1} = 13.9375$
$\frac{1}{\mathfrak{K}_2} = 19.3437$	$\frac{1}{\mathfrak{K}_3} = 97.990$	

Terms.

$\alpha\left(1+\frac{1}{\mathfrak{K}_1}\right) = 6.2558$

$\frac{b}{d}\left[\quad\right] = 7.13538$

$(\beta-\alpha)\left(1+\frac{1}{\mathfrak{K}_2}\right) = 18.96765$

$\frac{d}{r_2}\left[\quad\right] = 16.4038$

$\left(\frac{\pi}{2}-\beta\right)\left(1+\frac{1}{\mathfrak{K}_3}\right) = 21.52056$

$\frac{d}{r_3}\left(1+\frac{1}{\mathfrak{K}_3}\right)\left(\frac{\pi}{2}-\beta\right) = 6.9883$

$\frac{1}{\mathfrak{K}_1}\left(\frac{2\sin\alpha}{K} - \cos\alpha\right) = 1.58469$

$\frac{1}{\mathfrak{K}_2}(\cos\alpha - \cos\beta) = 13.4554$

$\frac{1}{\mathfrak{K}_3}\cos\beta = 21.3520$

$\frac{16e}{d^2} = 2.8750$

Coefficients.

Numerator +	Numerator −	Denominator +
7.1354	13.4554	6.2558
18.9676	21.3520	16.4038
21.5206	1.5847	6.9883
47.6236	36.3921	2.8750
36.3921		32.5229
11.2315		

$$M = \frac{-11.2315}{32.5229}Qd$$

$$M = -.3453\,Qd$$

Dredge Chain No. 6.

Bach Theory.

Calculations for deflections of Major Axis.

Terms.

$\frac{1}{\mathcal{R}_1}(1-\cos\alpha) = 1.2056$

$b[\quad] = 2.7503$

$\frac{d}{4K\mathcal{R}_1}(2\sin^4\alpha + \alpha^2 - 2\alpha\sin\alpha\cos\alpha + \sin^2\alpha) = 2.1938$

$\frac{1}{\mathcal{R}_2}(\cos\alpha - \cos\beta) = 13.4554$

$h[\quad] = 31.9567$

$\frac{r_2}{2\mathcal{R}_2}(\beta - \alpha + \sin\alpha\cos\alpha - \sin\beta\cos\beta) = 24.407$

$\frac{1}{r_2}(h-b)(1+\frac{1}{\mathcal{R}_2})(\beta-\alpha) = .7686$

$h[\quad] = 1.8254$

$(h-b)\frac{1}{\mathcal{R}_2}(\cos\alpha - \cos\beta) = 1.2613$

$\frac{r_3}{2\mathcal{R}_3}(\frac{\pi}{2} - \beta + \sin\beta\cos\beta) = 131.0543$

$\frac{1}{\mathcal{R}_3}\cos\beta = 21.3520$

$r_3[\quad] = 132.1155$

$\frac{r_3 - b}{r_3}(1+\frac{1}{\mathcal{R}_3})(\frac{\pi}{2}-\beta) = 13.5859$

$r_3[\quad] = 84.0630$

$(r_3 - b)\frac{1}{\mathcal{R}_3}\cos\beta = 84.405$

$e = .71875$

$\frac{16be}{d^2} = 6.5643$

Coefficients.

M. +	M. −	Q. +	Q. −
.7686	1.2056	2.1938	2.7503
13.5859	13.4554	1.8254	31.9567
14.3545	21.3520	131.0543	1.2613
	6.5643	84.0630	132.1155
	42.5773	.7187	83.4050
	14.3545	24.4070	251.4888
	−28.2228	244.2622	244.2622
			−7.2266

$$E \cdot f \cdot \Delta a = [(-28.2228 \times (-.6906)) - 7.2266] Q$$

$$\Delta a = \frac{12.2640}{3.1416 \times 30{,}000{,}000.} Q$$

$$\Delta a = 0.000\,000\,1315 Q$$

For modulus of 30,000,000. [Assumed].

Conveyor Chain No. 7.

Calculations for value of M Bach theory.

$r_2 = 1.2635$	$\tan\alpha = .3333$	$\beta = 78°\ 24.71'$
$i = 1.25$	$\alpha = 18°26'$	$\beta = 1.36855\ R.$
$h = 1.33 = \frac{4}{3}$	$\sin\alpha = .3162$	$\cos\beta = .20072$
$b = 1.25$	$\cos\alpha = .9487$	$\sin\beta = .97962$
$a = 2$	$\alpha = .3217\ R.$	$\sin\beta\cos\beta = .19663$
$l = 1.5$	$K = .6217$	$\beta - \alpha = 1.04685$
$r_2^2 = 1.59643$	$e = 1.5$	$\frac{\pi}{2} - \beta = .20225$
$d = 1.0$	$\alpha^3 = .03329$	$\alpha^2 = .10349$
$\frac{1}{\mathcal{H}_1} = 13.9375$	$\frac{1}{\mathcal{H}_2} = 23.504$	$\frac{1}{\mathcal{H}_3} = 397.9975$
$S = \frac{1}{12}$	$P = \frac{15}{4}$	$r_3 = 5.0$

Terms.

$\alpha\left(1+\frac{1}{\mathcal{H}_1}\right) = 4.80529$

$\frac{b}{d}\left[\qquad\right] = 6.00662$

$(\beta-\alpha)\left(1+\frac{1}{\mathcal{H}_2}\right) = 25.65203$

$\frac{d}{r_2}\left[\qquad\right] = 20.30233$

$\left(\frac{\pi}{2}-\beta\right)\left(1+\frac{1}{\mathcal{H}_3}\right) = 80.69724$

$\frac{d}{r_3}\left[\qquad\right] = 16.13945$

$16\frac{e}{d^2} = 24.00000$

$\frac{1}{\mathcal{H}_1}\left[\frac{2\sin\alpha}{K} - \cos\alpha\right] = 0.95486$

$\frac{1}{\mathcal{H}_2}(\cos\alpha - \cos\beta) = 17.58052$

$\frac{1}{\mathcal{H}_3}\cos\beta = 79.88606$

Coefficients-

Numerator +	Numerator −	Denominator +
6.00662	17.58052	4.80529
(25.65203 $\frac{l}{r_2}$	79.88606	20.30233
80.69724	.95486	16.13945
112.35589	98.42144	24.00000
98.42144		65.24707
13.93445		

2353

$$M = -\frac{13.93445}{65.24707}Qd = -0.21358\,Qd$$

Conveyor Chain No. 7.

Bach Theory.

Calculations for value of Major Axis.

$\frac{1}{\mathcal{K}_1}(1-\cos\alpha) = .71499$

$b[\quad] = .89374$

$\frac{1}{4K\mathcal{K}_1}\left[2\sin\alpha^4+\alpha^2-2\alpha\sin\alpha\cos\alpha+\sin^2\alpha\right] = 2.33408$

$\frac{1}{\mathcal{K}_2}(\cos\alpha-\cos\beta) = 17.58052$

$h[\quad] = 23.44068$

$\frac{r_2}{4\mathcal{K}_2}\left[(\beta-\alpha)+\sin\alpha\cos\alpha-\sin\beta\cos\beta\right] = 17.05071$

$\frac{1}{r_2}(h-b)\left(1+\frac{1}{\mathcal{K}_2}\right)(\beta-\alpha) = 1.62418$

$h[\quad] = 2.16556$

$16\frac{be}{d^2} = 30.00000$

$\frac{1}{\mathcal{K}_2}(h-b)(\cos\alpha-\cos\beta) = 1.40644$

$\frac{1}{\mathcal{K}_3}\cos\beta = 79.88607$

$r_3\frac{1}{\mathcal{K}_3}\cos\beta = 399.43035$

$\frac{r_3}{2\mathcal{K}_3}\left[\left(\frac{\pi}{2}-\beta\right)+\sin\beta\cos\beta\right] = 396.8830$

$\left(\frac{r_3-b}{r_3}\right)\left(1+\frac{1}{\mathcal{K}_3}\right)\left(\frac{\pi}{2}-\beta\right) = 60.52293$

$r_3[\quad] = 302.61465$

$\frac{1}{\mathcal{K}_3}(r_3-b)\cos\beta = 299.56273$

$e = 1.50000$

Coefficients.

M. +	M. −	Qd. +	Qd. −
1.62418	.71499	.17165	.89374
60.52293	17.58052	17.05071	23.44068
62.14721	79.88607	2.16556	1.40644
	30.00000	396.88300	399.43035
	128.18158	302.61465	299.57273
	62.14721	1.50000	724.74394
	−66.03437	720.38557	720.38557
			−4.35837

E.f. $\Delta a = (14.10494 - 4.35837)\,Qd$

$$\Delta a = \frac{9.74657}{22{,}305{,}000}\,Qd = 0.00436\,Qd$$

Conveyor Chain No. 7.

Bach Theory.

Calculations for deflections of Minor Axis.

$\frac{l}{d}\alpha\left(1+\frac{1}{\mathcal{K}_1}\right) = 7.2079$

$b[\qquad] = 9.0099$

$\frac{1}{\mathcal{K}_1}\sin\alpha = 4.4070$

$b[\qquad] = 5.5088$

$\frac{l}{\mathcal{K}_1}\left(\frac{2\sin\alpha}{K} - \cos\alpha\right) = 1.4321$

$\frac{d}{4\mathcal{K}_1}\left(2\sin^2\alpha + 1\right) = 4.1813$

$\frac{d}{2K\mathcal{K}_1}\alpha\cos^2\alpha = 3.2469$

$\frac{a-i}{r_2}\left(1+\frac{1}{\mathcal{K}_2}\right)(\beta-\alpha) = 15.2268$

$h[\qquad] = 20.3024$

$\frac{1}{\mathcal{K}_2}(\sin\beta - \sin\alpha) = 15.5925$

$h[\qquad] = 20.7900$

$\frac{a-i}{\mathcal{K}_2}(\cos\alpha - \cos\beta) = 13.1854$

$\frac{r_2}{2\mathcal{K}_2}(\sin^2\beta - \sin^2\alpha) = 12.7650$

$\frac{1}{\mathcal{K}_3}(1-\sin\beta) = 8.1191$

$r_3[\qquad] = 40.5955$

$\frac{r_3}{2\mathcal{K}_3}(1-\sin^2\beta) = 40.1987$

$\frac{8e^2}{d^2} = 18.0000$

Coefficients.

M.	Q	
+	+	−
7.2079	9.0099	1.4321
4.4070	5.5088	4.1813
15.2268	3.2469	13.1854
15.2925	20.3024	12.7650
8.1191	20.7900	40.1987
18.0000	40.5955	71.7625
68.5533	99.4535	
	71.7625	
	27.6910	

$$-E\cdot f\cdot\Delta b = (27.6910 - 14.6430)\,Q$$

$$\Delta b = -0.000000583\,Q$$

Conveyor Chain No. 7.

Ordinary Theory.

Calculations for the value of M.

$\alpha d = .3217$

$b\alpha d = .40213$

$r_2(\beta-\alpha) = 1.32269$

$r_2 h(\beta-\alpha) = 1.76358$

$r_3(\frac{\pi}{2}-\beta) = 1.01125$

$r_3^2(\frac{\pi}{2}-\beta) = 5.05625$

$r_2^2(\cos\alpha - \cos\beta) = 1.19431$

$r_3^2\cos\beta = 5.0175$

$e = 1.5$

$\frac{2d^2\sin\alpha}{K} = 1.01721$

$d^2\cos\alpha = .9487$

Coefficients.

Numerator +	Numerator −	Denominator +
1.19431	.40213	.32170
5.01750	1.76358	1.32269
1.01721	5.05625	1.01125
7.22902	.94870	1.50000
	8.17066	4.15564
	7.22902	
	-.94164	

$$M = -\frac{.94164}{4.15564}Q = -0.2266Q$$

Conveyor Chain No. 7.

Ordinary Theory.

Calculations for deflections of Major Axis.

$\frac{r_2}{2}(\beta-\alpha-\sin\beta\cos\beta+\sin\alpha\cos\alpha) = .57105$

$\frac{r_3}{2}(\frac{\pi}{2}-\beta+\sin\beta\cos\beta) = .9972$

$e = 1.5$

$16(1-\cos\alpha) = 0.8208$

$b[\quad] = 1.026$

$\frac{17d}{4K}[2\sin^4\alpha+\alpha^2-\alpha\sin\alpha\cos\alpha+\sin^2\alpha] = 2.26003$

$\frac{16r_2^2}{d^2}(\cos\alpha-\cos\beta) = 19.1051$

$h[\quad] = 25.4747$

$\frac{16Sr_2}{d^2}(\beta-\alpha) = 1.7635$

$h[\quad] = 2.35143$

$\frac{8r_2^3}{d^2}[\beta-\alpha-\sin\beta\cos\beta+\sin\alpha\cos\alpha] = 14.7436$

$\frac{16Sr_2^2}{d^2}(\cos\alpha-\cos\beta) = 1.5922$

$\frac{16r_3^2}{d^2}\cos\beta = 80.2880$

$r_3[\quad] = 401.4400$

$\frac{16Pr_3}{d^2}(\frac{\pi}{2}-\beta) = 60.0750$

$r_3[\quad] = 303.3750$

$\frac{8r_3^3}{d^2}[\frac{\pi}{2}-\beta+\sin\beta\cos\beta] = 398.8800$

$\frac{16r_3^2P}{d^2}\cos\beta = 301.0800$

$\frac{16be}{d^2} = 30.0000$

Coefficients-

M. +	M. −	Q. +	Q. −
1.7635	19.1051	.57105	1.02600
60.0750	.8208	2.26003	25.47470
61.8385	80.2880	.57722	1.59220
	30.0000	2.35143	401.44000
	130.2139	14.74360	301.08000
	61.8385	303.37500	730.61290
	−68.3754	1.50000	724.45830
		398.88000	−6.15460
		724.45830	

$\Delta a \cdot Ef = (15.4939 - 6.15460)Q$

$\Delta a = 0.000000418\,Q$

Conveyor Chain No. 7.

Ordinary Theory.

Calculations for deflection of Minor Axis.

$16(\alpha - \sin\alpha) = .0880$

$b[\qquad] = .1100$

$\frac{17d}{4K}\left[2\alpha\sin^2\alpha - (\alpha - \sin\alpha\cos\alpha)\right] = .3272$

$\frac{16d}{K}(\sin^3\alpha + \sin\alpha - \alpha\cos\alpha) = 1.09812$

$\frac{17}{2}d\sin^2\alpha = .8500$

$\frac{16ir_2}{d^2}(\beta - \alpha) = 26.4552$

$h[\qquad] = 33.0690$

$\frac{16r_2^2}{d^2}(\sin\beta - \sin\alpha) = 16.6251$

$h[\qquad] = 20.7814$

$\frac{16ir_2^2}{d^2}(\cos\alpha - \cos\beta) = 23.8826$

$\frac{8r_2^3}{d^2}(\sin^2\beta - \sin^2\alpha) = 13.8724$

$\frac{16ar_3}{d^2}(\frac{\pi}{2} - \beta) = 32.3600$

$\frac{16ar_3^2}{d^2}(\frac{\pi}{2} - \beta) = 161.8000$

$\frac{16r_3^2}{d^2}(1 - \sin\beta) = 8.1520$

$r_3[\qquad] = 40.7600$

$\frac{16r_3^2 a\cos\beta}{d^2} = 160.5600$

$\frac{8r_3^3}{d^2}\cos^2\beta = 40.3500$

$\frac{8(2ae+e^2)}{d^2} = 66.0000$

$\frac{r_2}{2}(\sin^2\beta - \sin^2\alpha) = .5431$

$\frac{r_3}{2}\cos^2\beta = .1009$

Coefficients-

M. +	M. −	Q +	Q −
.0880	16.6251	.1100	1.0981
26.4552	8.1520	.3272	20.7814
32.3600	24.7771	.8500	23.8826
66.0000		33.0690	40.7600
124.9032		13.8724	160.5600
24.7771		161.8000	247.0821
100.1261		40.3500	
		.5431	
		.1009	
		251.0226	
		247.0821	
		3.9405	

$E.f.\Delta b = (-22.6886 - 3.9405)Q$

$\Delta b = -0.000000842\,Q$

Dredge Chain. No. 8.

Bach Theory.

Calculations for value of M.

$d = .997$	$\alpha = 19°30'$	$\beta = 77°30'$
$r_2 = 1.2$	$\sin\alpha = .33381$	$\cos\beta = .21644$
$r_3 = 5$	$\cos\alpha = .94264$	$\sin\beta = .9763$
$i = 1.16$	$\alpha = .3400\ R.$	$\beta = 1.3526$
$h = 1.26$	$K = .65466$	$\sin\beta\cos\beta = .21127$
$b = 1.1875$	$\sin\alpha\cos\alpha = .31466$	$\beta - \alpha = 1.0126$
$a = 1.8750$	$d^2 = .99401$	$\frac{\pi}{2} - \beta = .2182$
$l = 0.878$	$p = 3.6875$	$\cos\alpha - \cos\beta = .7262$
$r_2^2 = 1.44$	$\frac{1}{\mathcal{K}_1} = 13.93$	$\frac{1}{\mathcal{K}_2} = 21.996$
$s = \frac{1}{12}$	$\frac{1}{\mathcal{K}_3} = 397.975$	

Terms.

$\alpha\left(1+\frac{1}{\mathcal{K}_1}\right) = 5.0762$	$\frac{d}{r_2}\left(1+\frac{1}{\mathcal{K}_2}\right)(\beta-\alpha) = 18.5610$	$\frac{1}{\mathcal{K}_2}(\cos\alpha - \cos\beta) = 15.2473$
$\frac{b}{d}[\quad] = 6.0278$	$\left(\frac{\pi}{2}-\beta\right)\left(1+\frac{1}{\mathcal{K}_3}\right) = 87.0563$	$\frac{1}{\mathcal{K}_3}\cos\beta = 86.13771$
$(\beta-\alpha)\left(1+\frac{1}{\mathcal{K}_2}\right) = 22.2732$	$\frac{d}{r_3}[\quad] = 17.4113$	$\frac{1}{\mathcal{K}_1}\left(\frac{2\sin\alpha}{K} - \cos\alpha\right) = 1.07609$

Coefficients.

Numerator +	Numerator −	Denominator +
6.0278	15.24730	5.0762
22.2732	86.13771	18.5610
87.0563	1.07609	17.4113
115.3573	102.46110	41.0485
102.4611		
12.8962		

$$M = -\frac{12.8962}{41.0485}Qd$$

$$M = -0.31416\ Qd$$

Dredge Chain No. 8.

Bach Theory.

Calculations for deflection of Major Axis.

$\frac{1}{\mathcal{H}_1}(1-\cos\alpha) = .79902$

$b[\quad] = .94884$

$\frac{d}{4K\mathcal{H}_1}\left[2\sin^4\alpha + \alpha^2 - 2\alpha\sin\alpha\cos\alpha + \sin^2\alpha\right] = .20157$

$\frac{1}{\mathcal{H}_2}(\cos\alpha - \cos\beta) = 15.24729$

$h[\quad] = 19.21159$

$\frac{r_2}{2\mathcal{H}_2}\left[\beta - \alpha + \sin\alpha\cos\alpha - \sin\beta\cos\beta\right] = 14.05880$

$\frac{1}{r_2}(h-b)\left(1+\frac{1}{\mathcal{H}_2}\right)(\beta-\alpha) = 1.34567$

$h[\quad] = 1.69554$

$\frac{1}{\mathcal{H}_2}(h-b)(\cos\alpha - \cos\beta) = 1.10543$

$\frac{1}{\mathcal{H}_3}\cos\beta = 86.13771$

$r_3[\quad] = 430.68855$

$\frac{r_3}{2\mathcal{H}_3}\left(\frac{\pi}{2} - \beta + \sin\beta\cos\beta\right) = 427.29580$

$\frac{r_3 - b}{r_3}\left(\frac{\pi}{2} - \beta\right)\left(1+\frac{1}{\mathcal{H}_3}\right) = 66.38043$

$(r_3 - b)\frac{1}{\mathcal{H}_3}\cos\beta = 328.40002$

$(r_3 - b)\left(\frac{\pi}{2} - \beta\right)\left(1+\frac{1}{\mathcal{H}_3}\right) = 331.90215$

Coefficients.

M. +	M. −	Q. +	Q. −
1.34567	.79902	.20157	.94884
66.38043	15.24729	14.05880	19.21159
67.72610	86.13771	1.69554	1.10543
	102.18402	427.29580	430.68855
	67.72610	331.90215	328.40002
	−34.45792	775.15386	780.35443
			775.15386
			−5.20057

$E \cdot f \cdot \Delta a = -34.45792\,M - 5.20057$

$\Delta a = \frac{5.62473}{24{,}600{,}000 \times .7854}\,Q$

$\Delta a = 0.000000291\,Q$

Dredge Chain No. 8.

Bach Theory.

Calculations for deflections of Minor Axis.

Terms.

$\alpha\left(1+\frac{1}{\mathcal{K}_1}\right) = 5.07620$

$b[\quad] = 6.02799$

$\frac{1}{\mathcal{K}_1}\sin\alpha = 4.64997$

$b[\quad] = 5.52184$

$\frac{d}{K\mathcal{K}_1}(\sin^3\alpha + \sin\alpha - \alpha\cos\alpha) = 1.07485$

$\frac{d}{4\mathcal{K}_1}(2\sin^2\alpha + 1) = 4.25861$

$\frac{d}{2K\mathcal{K}_1}\alpha\cos^2\alpha = 3.21457$

$\frac{i}{r_2}\left(1+\frac{1}{\mathcal{K}_2}\right)(\beta-\alpha) = 21.53061$

$h[\quad] = 27.12857$

$\frac{i}{\mathcal{K}_2}(\cos\alpha - \cos\beta) = 17.68686$

$\frac{1}{\mathcal{K}_2}(\sin\beta - \sin\alpha) = 13.48972$

$h[\quad] = 16.99705$

$\frac{r_2}{2\mathcal{K}_2}(\sin^2\beta - \sin^2\alpha) = 10.66318$

$\frac{a}{r_3}\left(1+\frac{1}{\mathcal{K}_3}\right)\left(\frac{\pi}{2}-\beta\right) = 32.64611$

$r_3[\quad] = 163.23055$

$\frac{a}{\mathcal{K}_3}\cos\beta = 161.50821$

$\frac{1}{\mathcal{K}_3}(1-\sin\beta) = 9.43201$

$r_3[\quad] = 47.16005$

$\frac{r_3}{2\mathcal{K}_3}(1-\sin^2\beta) = 46.60288$

Coefficients.

M. +	M. −	Q +	Q −
5.07620	4.64997	6.02799	5.52184
21.53061	13.48972	4.25861	1.07485
32.64611	9.43201	27.12857	3.21457
59.25292	27.57170	10.66318	17.68686
27.57170		163.23055	16.99705
31.68122		46.60288	161.50821
		257.91178	47.16005
		253.16343	253.16343
		4.74835	

$E \cdot f.\ \Delta b = 31.68122\,M + 4.74835\,Q$

$$\Delta b = \frac{-5.20462}{24{,}600{,}000 \times .7854}\,Q$$

$$\Delta b = -0.000000269\,Q$$

Dredge Chain No. 8.

Ordinary Theory.

Calculations for value of M.

Terms.

$\alpha d = .33898$

$b\alpha d = .40254$

$r_2(\beta - \alpha) = 1.21512$

$h[\quad] = 1.53105$

$r_3(\frac{\pi}{2} - \beta) = 1.0910$

$r_3^2(\frac{\pi}{2} - \beta) = 5.4550$

$r_2^2(\cos\alpha - \cos\beta) = 1.04573$

$r_3^2(\cos\beta) = 5.4110$

$K = .65466$

$\frac{2d^2 \sin\alpha}{K} = 1.01368$

$d^2 \cos\alpha = .93699$

Coefficients.

Numerator +	Numerator −	Denominator +
1.04573	.40254	.33898
5.41100	1.53105	1.21512
1.01721	5.45500	1.09100
7.47394	.93699	2.64510
	8.32558	
	7.47394	
	− .85164	

$$M = \frac{-.85164}{2.6451} Q$$

$$M = -.3220 Q$$

Dredge Chain No. 8.

Ordinary Theory.

Calculations for deflections of Majar Axis.

Terms.

$\frac{r_2}{2}(\beta-\alpha-\sin\beta\cos\beta+\sin\alpha\cos\alpha) = .2920$

$\frac{r_3}{2}(\frac{\pi}{2}-\beta+\sin\beta\cos\beta) = 1.07368$

$16(1-\cos\alpha) = .91776$

$b[\qquad] = 1.08984$

$\frac{17d}{4K}(2\sin^4\alpha+\alpha^2-\alpha\sin\alpha\cos\alpha+\sin^2\alpha) = .93775$

$\frac{16r_2^2}{d^2}(\cos\alpha-\cos\beta) = 16.83267$

$h[\qquad] = 21.20912$

$\frac{16Sr_2}{d^2}(\beta-\alpha) = 1.63$

$h[\qquad] = 2.0538$

$\frac{8r_2^3}{d^2}(\beta-\alpha-\sin\beta\cos\beta+\sin\alpha\cos\alpha) = 15.52056$

$\frac{16Sr_2^2}{d^2}(\cos\alpha-\cos\beta) = 1.40271$

$\frac{16r_3^2}{d^2}\cos\beta = 87.09859$

$r_3[\qquad] = 435.49295$

$\frac{16pr_3}{d^2}(\frac{\pi}{2}-\beta) = 64.75754$

$\frac{16pr_3^2}{d^2}(\frac{\pi}{2}-\beta) = 323.78770$

$\frac{8r_3^3}{d^2}(\frac{\pi}{2}-\beta+\sin\beta\cos\beta) = 432.06237$

$\frac{16r_3^2}{d^2}p\cos\beta = 321.1167$

Coefficients.

M. +	M. −	Q. +	Q. −
1.63000	.91776	.29200	1.08984
64.75754	16.83267	1.07368	21.20912
66.38754	87.09859	.93775	1.40271
	104.84902	2.05380	435.49295
	66.38754	15.52056	321.11670
	−38.46148	323.78770	780.31132
		432.06237	775.72786
		775.72786	−4.58346

$E \cdot f. \Delta a = -38.46148\,M - 4.58346\,Q$

$\Delta a = +\frac{7.8011}{19,320,840}\,Q = 0.0000004037\,Q$

Dredge Chain No. 8.

Ordinary Theory.

Calculations for deflections of Minor Axis.

Terms.

$16(\alpha - \sin\alpha) = .09904$

$b[\qquad] = .11761$

$\frac{17}{4K}(2\alpha\sin^2\alpha - \alpha + \sin\alpha\cos\alpha) = .32732$

$\frac{16d}{K}(\sin^3\alpha + \sin\alpha - \alpha\cos\alpha) = 1.23077$

$\frac{17}{2}\sin^2\alpha = .9471$

$\frac{16 i r_2}{d^2}(\beta - \alpha) = 22.6881$

$h[\qquad] = 28.5870$

$\frac{16 r_2^2}{d^2}(\sin\beta - \sin\alpha) = 14.8923$

$h[\qquad] = 18.7643$

$\frac{16 i r_2^2}{d^2}(\cos\alpha - \cos\beta) = 19.4970$

$\frac{8 r_2^3}{d^2}(\sin^2\beta - \sin^2\alpha) = 11.7072$

$\frac{16 a r_3}{d^2}(\frac{\pi}{2} - \beta) = 32.9276$

$r_3[\qquad] = 164.6380$

$\frac{16 r_3^2}{d^2}(1 - \sin\beta) = 9.5371$

$r_3[\qquad] = 47.6855$

$\frac{16 r_3^2}{d^2} a \cos\beta = 163.2796$

$\frac{8 r_3^3}{d^2}\cos^2\beta = 47.0824$

$\frac{r_2}{2}(\sin^2\beta - \sin^2\alpha) = .50508$

$\frac{r_3}{2}\cos^2\beta = .1170$

Coefficients.

M. +	M. —	Q. +	Q. —
.09904	14.8923	.1176	1.2307
22.68810	9.5371	.3273	18.7643
32.92760	24.4294	.9471	19.4970
55.71474		28.5870	47.6855
24.42940		11.7072	163.2796
31.28534		164.6380	250.4572
		47.0824	
		.5051	
		.1170	
		254.0287	
		250.4572	
		3.5715	

$E \cdot f \cdot \Delta b = 31.2853 M + 3.5715$

$\Delta b = \frac{-6.5024}{19,320,840} Q = -0.000000336 Q$

Test #1

Sample #1

Mild Steel

Load	Readings		Elongation		Average
0 #	.0128	.0157	——	——	——
1000	.0143	.0172	.0015	.0015	.0015
2000	.0152	.0183	.0024	.0026	.0025
3000	.0156	.0196	.0028	.0039	.0034
4000	.0157	.0214	.0029	.0057	.0043
5000	.0157	.0213	——	——	——
6000	.0159	.0249	.0031	.0092	.0062
7000	.0165	.0309	.0037	.0152	.0094
8000	.0172	.0316	.0044	.0159	.0101
9000	.0187	.0325	.0059	.0168	.0114
9360	.0229	.0394	.0091	.0237	.0164

Diameter. ——— ——— .647"

Stock. ——— ——— Steel Casting

Modulus. ——— ——— 26,200,000

Elastic Limit. ——— ——— 27,400#

Max. Load. ——— ——— 37,000#

Elongation. ——— ———

Test #3 Sample #1

12" RING [Steel Casting]

Load	Readings Horizontal	Readings Vertical	Deformations Horizontal	Deformations Vertical
500	.2420	.2408	——	——
1,000	.2419	.2379	-.0001	.0029
1,500	.2442	.2367	.0022	.0041
2,020	.2467	.2357	.0047	.0051
2,500	.2474	.2342	.0054	.0066
3,000	.2484	.2322	.0064	.0086
3,500	.2494	.2306	.0074	.0102
4,000	.2503	.2277	.0083	.0131
4,500	.2529	.2284	.0109	.0124
5,000	.2536	.2270	.0116	.0138
5,500	.2546	.2256	.0126	.0152
5,900	.2550	.2249	.0130	.0159
6,500	.2572	.2234	.0152	.0174
7,000	.2583	.2218	.0163	.0190
7,500	.2600	.2187	.0180	.0221

Outside Diameter ---12.000"

Inside Diameter ---9.000"

Width ------------ 1.0476"

Test #4 Sample #1

12" Ring [Steel Casting]

Load	Readings Hor.	Readings Ver.	Deformations Hor.	Deformations Ver.
0	.9985	.0024	——	——
500	.9973	.0048 ?	.0012	.0024
1,000	.9960	.0045	.0025	.0021
1,500	.9948	.0057	.0036	.0033
2,000	.9933	.0073	.0052	.0049
2,500	.9917	.0085	.0068	.0061
3,000	.9913	.0098	.0072	.0074
3,500	.9907	.0116	.0078	.0092
4,000	.9890	.0130	.0095	.0106
4,500	.9874	.0143	.0111	.0119
5,000	.9863	.0156	.0122	.0132
5,500	.9851	.0170	.0134	.0146
6,000	.9840	.0184	.0145	.0160
6,500	.9824	.0199	.0161	.0175
7,000	.9808	.0213	.0177	.0189
7,500	.9800	.0223	.0185	.0199

Check Test.

Outside Diam.---12.000"

Inside Diam.--- 9.000"

Width ------- 1.0476"

Test #5 Sample #2

12" RING [Steel Casting]

Load	Readings		Deformations.	
	Hor.	Ver.	Hor.	Ver.
0	.0076	.0043	———	———
500	.0054	.0062	.0022	.0019
1,000	.0047	.0063	.0029	.0020
1,500	.0036	.0087	.0040	.0044
2,000	.0018	.0102	.0058	.0059
2,500	.0007	.0120	.0069	.0077
3,000	.9994	.0135	.0082	.0092
3,500	.9975	.0138	.0101	.0095
4,000	.9958	.0153	.0118	.0110
4,500	.9953	.0167	.0123	.0124
5,000	.9932	.0177	.0144	.0134
5,500	.9920	.0199	.0156	.0156
6,000	.9917	.0217	.0159	.0174
6,500	.9905	.0230	.0171	.0187
7,000	.9887	.0249	.0189	.0206
7,500	.9870	.0270	.0206	.0227

Outside Diam.----12.0056"

Inside " ------ 9.000"

Thickness ------- 1.005"

Test #6

Sample #2

12" RING [Steel Casting]

Load	Reading Hor.	Reading Ver.	Deformation Hor.	Deformation Ver.
0	1.0050	.0062	———	———
500	1.0028	.0067	.0022	.0005
1,000	1.0023	.0082	.0027	.0020
1,500	1.0018	.0100	.0032	.0038
2,000	.9994	.0106	.0056	.0044
2,500	.9991	.0130	.0059	.0068
3,000	.9964	.0148	.0086	.0084
3,500	.9960	.0158	.0090	.0096
4,000	.9943	.0170	.0107	.0108
4,500	.9932	.0186	.0118	.0124
5,000	.9919	.0196	.0131	.0134
5,500	.9908	.0220	.0142	.0158
6,000	.9899	.0230	.0151	.0168
6,500	.9884	.0240	.0166	.0178
7,000	.9871	.0255	.0179	.0193
7,500	.9860	.0270	.0190	.0208

Check Test

Outside Diam. —— 12.0056"

Inside " ---- 9.000"

Thickness ---—— 1.005"

Test #2

Sample #3

MILD STEEL

Load	Readings		Elongation		Average.
0 #	.0050	.0133	——	——	——
2000	.0019	.0173	-.0031	.0040	.00045
4000	-.0014	.0220	-.0064	.0087	.00065
6000	-.0032	.0251	-.0082	.0118	.0018
8000	-.0038	.0269	-.0058	.0136	.0024
1,0000	-.0031	.0273	-.0081	.0140	.00295
1,2000	-.0020	.0279	-.0070	.0146	.0038
1,4000	-.0006	.0281	-.0056	.0148	.0046
1,6000	.0005	.0279	-.0045	.0146	.00505
1,8000	.0018	.0283	-.0032	.0150	.0059
2,0000	.0029	.0284	-.0021	.0151	.0065
2,2000	.0043	.0289	-.0007	.0156	.00745
2,4000	.0056	.0290	.0006	.0157	.00815
2,6000	.0165	.0378	.0115	.0245	.0180

Stock ------- Forging

Diameter --------1.000"

Modulus -------- 30,400,000

Elastic Limit----- 28,000

Max. Load ------- 48,300

Elongation --------

Test #7 Sample #3

12" Ring [Forging]

Load	Reading Hor.	Reading Ver.	Deformations Hor.	Deformations Ver.
0	.0063	.0050	.0	.0
500	.0085	.0036	.0014	.0022
1000	.0094	.0025	.0025	.0031
1500	.0101	.0007	.0043	.0038
2000	.0115	.9996	.0054	.0052
2500	.0113	.9987	.0063	.0070
3000	.0147	.9969	.0081	.0084
3500	.0154	.9969	.0081	.0091
4000	.0171	.9946	.0104	.0108
4500	.0184	.9930	.0120	.0121
5000	.0195	.9925	.0125	.0131
5500	.0206	.9913	.0137	.0143
6000	.0220	.9900	.0150	.0157
6500	.0228	.9887	.0163	.0165
7000	.0245	.9877	.0173	.0182
7500	.0261	.9871	.0179	.0198
8000	.0287	.9852	.0198	.0224

Outside Diam.-----12.007"

Inside Diam.---- 9.001"

Width --------- 1.00"

Test #8 Sample #3

12" Ring [Forging]

Load	Reading Ver.	Reading Hor.	Deformations Ver.	Deformations Hor.
0	.0063	.0032	.0	.0
500	.0070	.0014	.0003	.0018
1000	.0094	.0012	.0027	.0020
1500	.0102	.0003	.0035	.0029
2000	.0124	.9994	.0057	.0038
3000	.0133	.9960	.0076	.0072
3500	.0143	.9946	.0086	.0086
4000	.0153	.9935	.0103	.0097
4500	.0170	.9926	.0115	.0106
5000	.0182	.9916	.0133	.0116
5500	.0200	.9902	.0140	.0130
6000	.0207	.9992	.0155	.0140
6500	.0222	.9883	.0163	.0150
7000	.0230	.9871	.0179	.0161
7500	.0257	.9860	.0190	.0172
8000	.0273	.9836	.0206	.0196

Check Test.

Test #9 Sample #6

2" – CHAIN [B.B.B. DREDGE]

Load	Reading Hor.	Reading S.Ver.	Reading N.Ver.	Deformations Hor.	Deformations S.Ver.	Deformations N.Ver.	Average Ver.
0	.5907	.0215	.5488	—	—	—	—
3,000	.5900	.0223	.5496	.0007	.0008	.0008	.0008
6,000	.5895	.0225	.5501	.0012	.0010	.0013	.0012
9,000	.5892	.0230	.5511	.0015	.0015	.0017	.0016
12,000	.5889	.0231	.5518	.0018	.0016	.0023	.0020
15,000	.5886	.0238	.5524	.0021	.0023	.0030	.0027
18,000	.5882	.0240	.5528	.0025	.0025	.0036	.0032
21,000	.5879	.0244	.5531	.0028	.0029	.0040	.0035
24,000	.5876	.0245	.5535	.0031	.0031	.0043	.0037
27,000	.5872	.0249	.5538	.0035	.0034	.0047	.0041
30,000	.5868	.0253	.5540	.0039	.0038	.0050	.0044
33,000	.5864	.0254	.5543	.0043	.0039	.0052	.0046
36,000	.5864	.0258	.5549	.0043	.0043	.0055	.0049
39,000	.5869	.0263	.5551	.0048	.0048	.0061	.0055
42,000	.5857	.0265	.5555	.0050	.0050	.0063	.0057
45,000	.5855	.0269	.5561	.0052	.0054	.0067	.0061
48,000	.5852	.0273	.5563	.0055	.0058	.0073	.0066
51,000	.5849	.0277	.5568	.0058	.0062	.0075	.0068
54,000	.5845	.0280	.5568	.0062	.0065	.0080	.0073
57,000	.5840	.0283	.5576	.0067	.0068	.0082	.0075
60,000	.5838	.0295	.5578	.0069	.0070	.0090	.0080

[See d'w'g for dimensions]

Test #10 Sample #6

2" – CHAIN [B.B.B. DREDGE]

Load	Reading Hor.	Reading S.Ver.	Reading N.Ver.	Deformations Hor.	Deformations S. Ver.	Deformations N.Ver.	Average Ver.
0	.5902	.0216	.5495	———	———	———	———
3,000	.5898	.0219	.5502	.0004	.0003	.0007	.0005
6,000	.5890	.0223	.5505	.0012	.0007	.0010	.00085
9,000	.5887	.0228	.5514	.0015	.0012	.0019	.00155
12,000	.5880	.0230	.5523	.0022	.0014	.0028	.0021
15,000	.5876	.0235	.5530	.0026	.0019	.0035	.0027
18,000	.5872	.0238	.5532	.0030	.0022	.0037	.00295
21,000	.5870	.0241	.5535	.0032	.0025	.0040	.00325
24,000	.5867	.0242	.5540	.0035	.0026	.0045	.00355
27,000	.5865	.0246	.5540	.0037	.0030	.0045	.00375
30,000	.5862	.0247	.5543	.0040	.0031	.0048	.00395
33,000	.5860	.0251	.5548	.0042	.0035	.0053	.0044
36,000	.5856	.0255	.5552	.0046	.0039	.0057	.0048
39,000	.5855	.0259	.5558	.0047	.0043	.0063	.0053
42,000	.5851	.0260	.5560	.0051	.0044	.0065	.00545
45,000	.5845	.0265	.5562	.0057	.0049	.0067	.0058
48,000	.5843	.0270	.5568	.0059	.0054	.0073	.00635
51,000	.5838	.0275	.5570	.0064	.0059	.0075	.0067
54,000	.5838	.0278	.5571	.0067	.0062	.0076	.0069
57,000	.5831	.0280	.5573	.0071	.0064	.0078	.0071
60,000	.5827	.0285	.5580	.0075	.0068	.0085	.0077

Test #11 Sample #7

Conveyor Chain.

Load #	Reading Hor	Reading S.Ver.	Reading N.Ver.	Deformations Hor.	Deformations S.Ver.	Deformations N.Ver.	Average Ver.
0	.4875	.1363	.0400	———	———	———	———
2000	.4880	.1368	.0399	.-0005	.0005	-.0001	.0002
4000	.4863	.1390	.0404	.0005	.0027	.0004	.00155
6000	.4853	.1401	.0416	.0012	.0038	.0016	.0027
8000	.4840	.1410	.0417	.0022	.0047	.0017	.0032
10000	.4830	.1420	.0425	.0038	.0062	.0022	.0042
12000	.4814	.1427	.0430	.0043	.0069	.0027	.0048
14000	.4800	.1434	.0443	.0061	.0076	.0040	.0058
16000	.4782	.1443	.0452	.0075	.0085	.0049	.0067
18,000	.4766	.1458	.0459	.0109	.0100	.0056	.0078
20000	.4740	.1470	.0470	.0135	.0112	.0067	.00875
22000	.4710	.1499	.0480	.0165	.0141	.0077	.0109
24000	.4660	.1533	.0512	.0215	.0175	.0109	.0142
25000	.4620	.1569	.0515	.0255	.0211	.0148	.01795

[See d'w'g for dimensions]

Test #12 Sample #7

CONVEYOR CHAIN.

Load #	Reading Hor.	Reading S.Ver.	Reading N.Ver.	Deformations Hor.	Deformations S.Ver.	Deformations N.Ver.	Average Ver.
0	.4013	.1835	.0292	——	——	——	——
2000	.3996	.1840	.0295	.0003	.0005	.0003	.0004
4000	.3996	.1848	.0302	.0017	.0013	.00115	.0010
6000	.3981	.1858	.0312	.0032	.0023	.0020	.00215
8000	.3969	.1864	.0319	.0044	.0029	.0027	.0028
10000	.3960	.1873	.0326	.0053	.0038	.0034	.0036
12000	.3949	.1882	.0332	.0064	.0045	.0037	.0041
14000	.3942	.1890	.0341	.0077	.0047	.0040	.00435
16000	.3924	.1895	.0347	.0089	.0051	.0044	.00475
18000	.3914	.1898	.0346	.0099	.0063	.0064	.00635
20000	.3904	.1910	.0359	.0109	.0075	.0067	.0071
22,000	.3893	.1922	.0367	.0120	.0087	.0075	.0081
24000	.3878	.1923	.0378	.0135	.0093	.0086	.00895

Check Test.

Test #13 Sample 8

Dredge Chain.

Load #	Reading Hor.	Reading S.Ver.	Reading N.Ver.	Deformations Hor.	Deformations S.Ver.	Deformations N.Ver.	Average Ver.
1000	.5100	.0098	.0125	.——	.——	.——	.——
2000	.5099	.0101	.0129	.0001	.0003	.0004	.00035
4000	.5092	.0106	.0136	.0008	.0008	.0011	.00095
6000	.5080	.0109	.0138	.0020	.0011	.0013	.0012
8000	.5080	.0112	.0149	.0020	.0014	.0024	.0019
10000	.5074	.0119	.0152	.0026	.0021	.0027	.0024
12000	.5070	.0124	.0158	.0030	.0026	.0033	.00295
14000	.5065	.0129	.0163	.0035	.0031	.0038	.00345
16000	.5057	.0132	.0171	.0043	.0034	.0046	.0040
18000	.5049	.0142	.0188	.0051	.0044	.0063	.00535
20000	.5030	.0161	.0199	.0070	.0063	.0074	.00685
22000	.4969	.0216	.0267	.0131	.0118	.0142	.0130

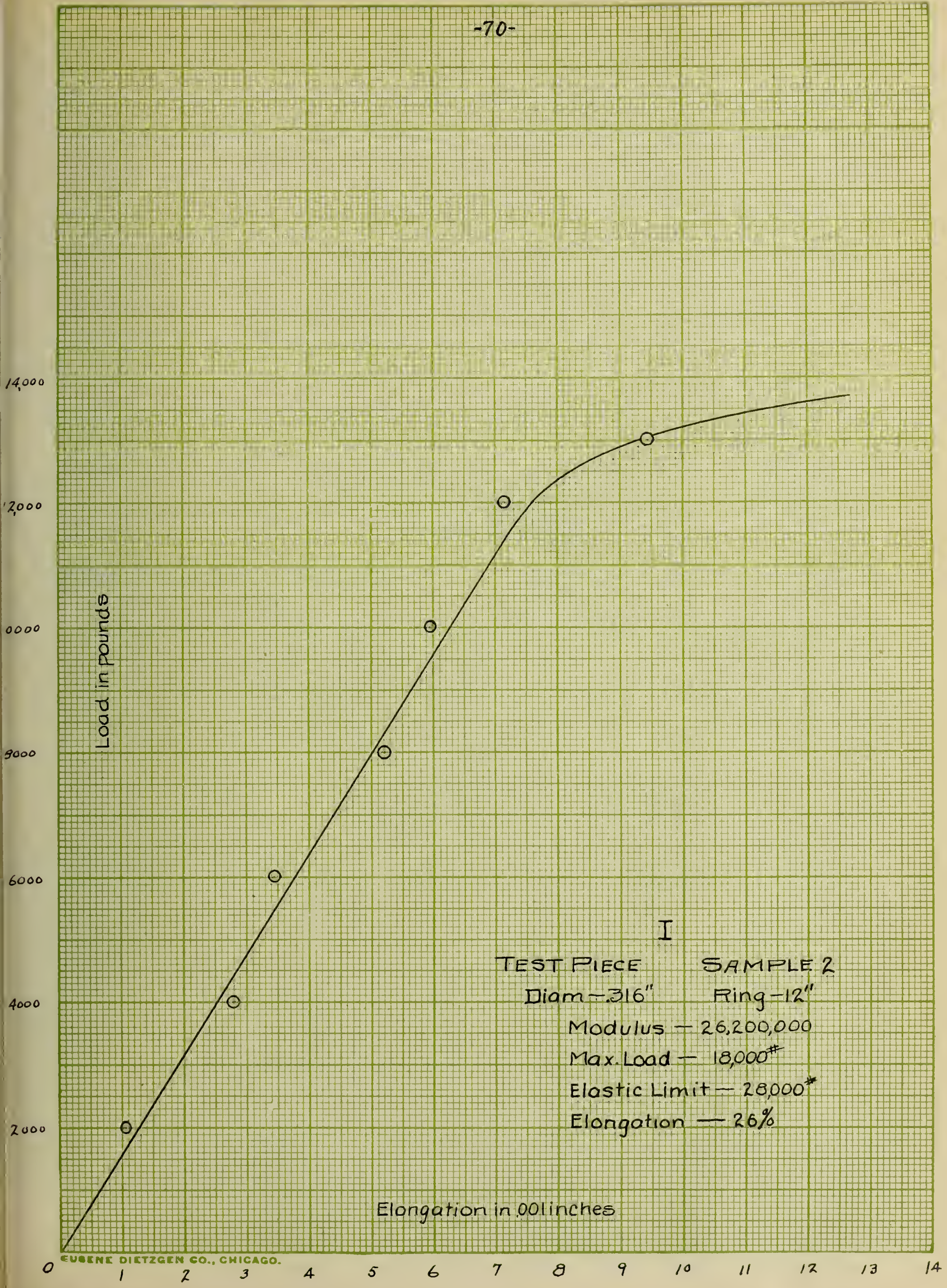
[See dwg. # for dimensions]

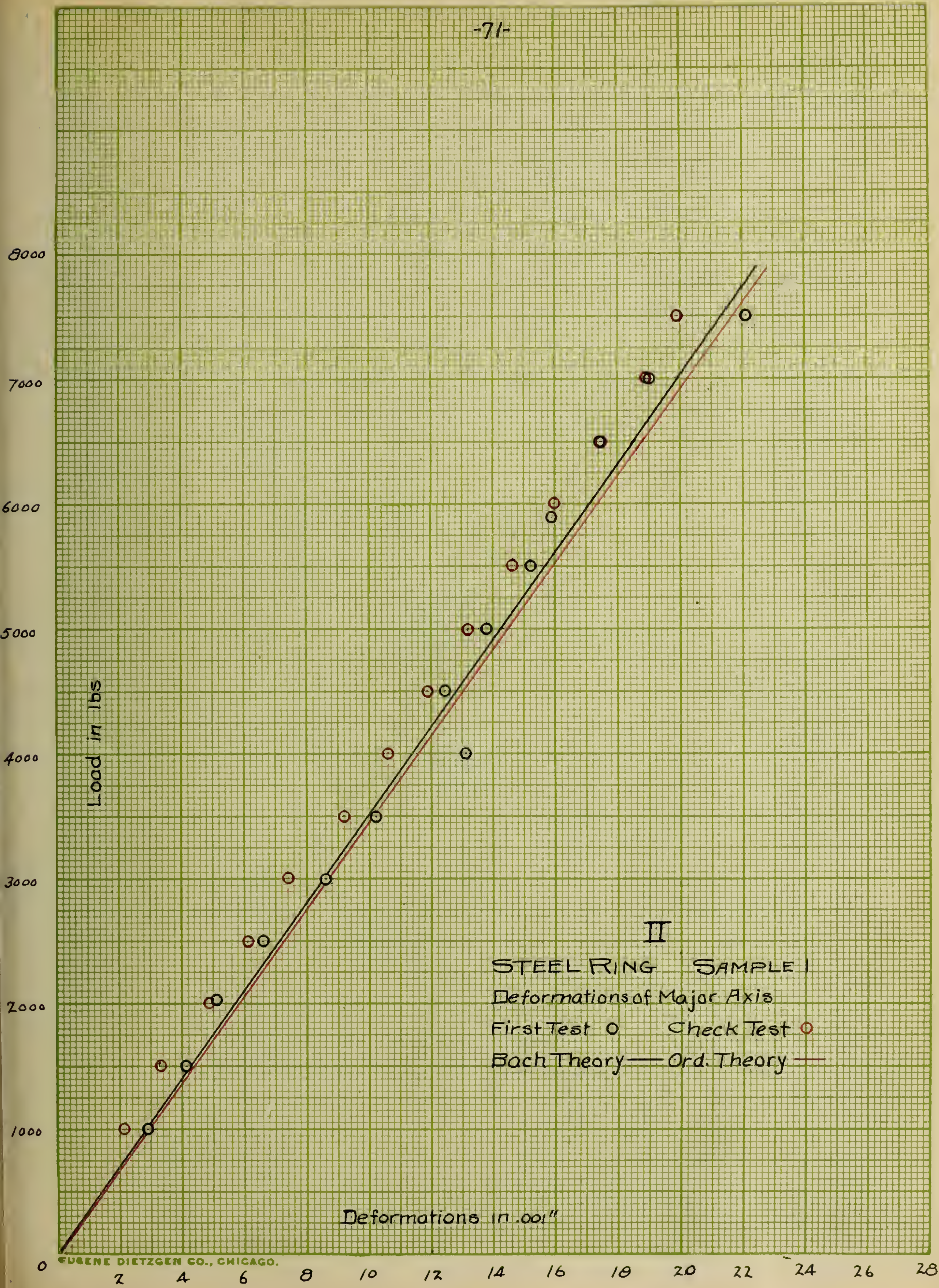
Test #14 Sample 8.

DREDGE CHAIN.

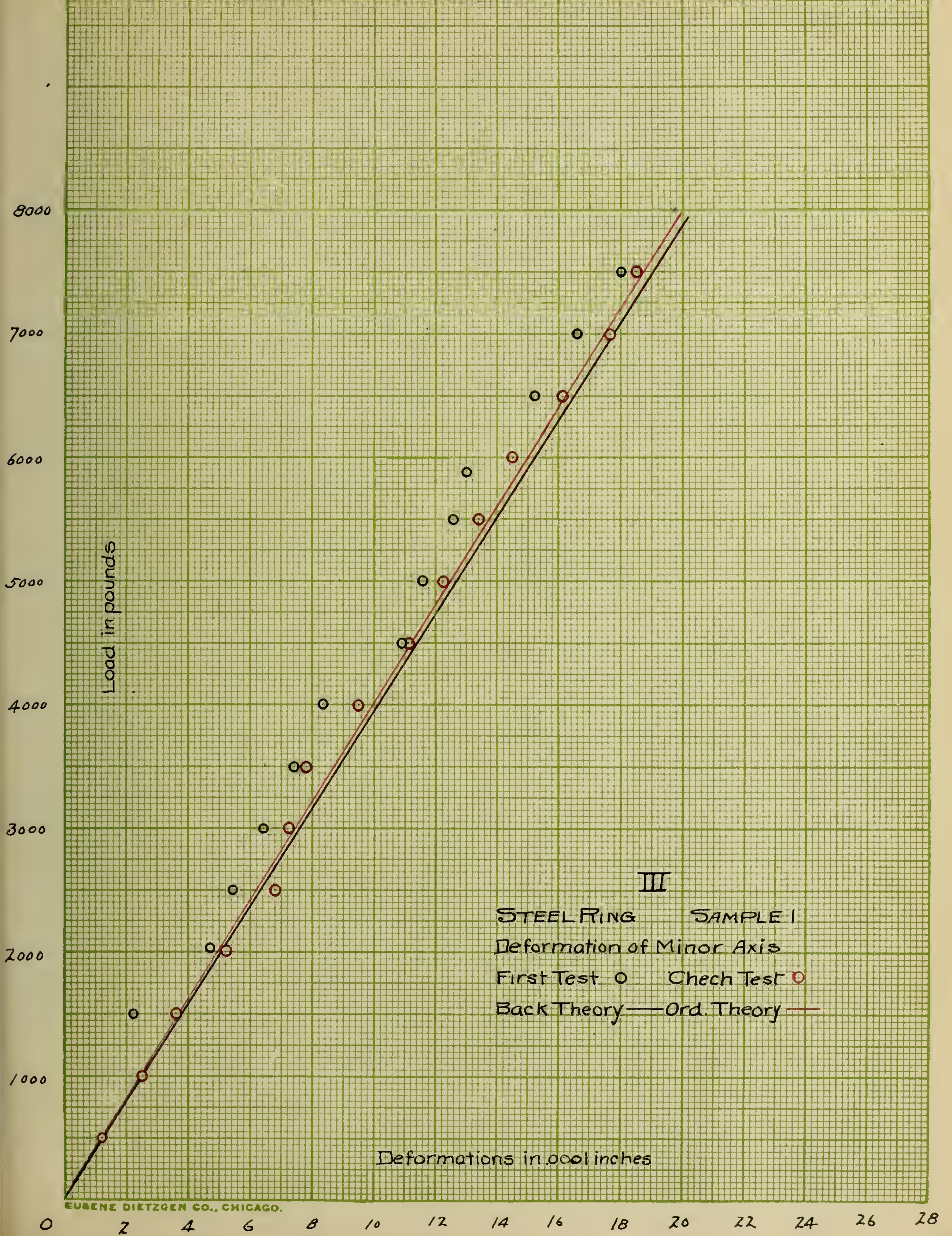
Load	Reading Hor.	Reading S. Ver.	Reading N. Ver.	Deformations Hor.	Deformations S. Ver.	Deformations N. Ver.	Average Ver.
1,000	.2036	.0033	.0035	———	———	———	———
2,000	.0035	.0038	.0038	.0001	.0002	.0003	.00025
4,000	.2034	.0038	.0045	.0002	.0005	.0010	.00075
6,000	.2030	.0042	.0054	.0006	.0009	.0019	.0014
8,000	.2024	.0048	.0062	.0012	.0015	.0027	.0021
10,000	.2016	.0048	.0072	.0020	.0015	.0037	.0026
12,000	.2013	.0051	.0078	.0023	.0018	.0043	.00305
14,000	.2010	.0059	.0085	.0026	.0026	.0050	.0038
16,000	.1999	.0061	.0088	.0037	.0028	.0053	.00405
18,000	.1997	.0058	.0101	.0039	.0025	.0066	.00455
20000	.1990	.0068	.0111	.0046	.0033	.0076	.00545
22,000	.1981	.0069	.0120	.0055	.0036	.0085	.00605
24,000	———	.0326	.0248	———	.0293	.0213	.0253

Check Test

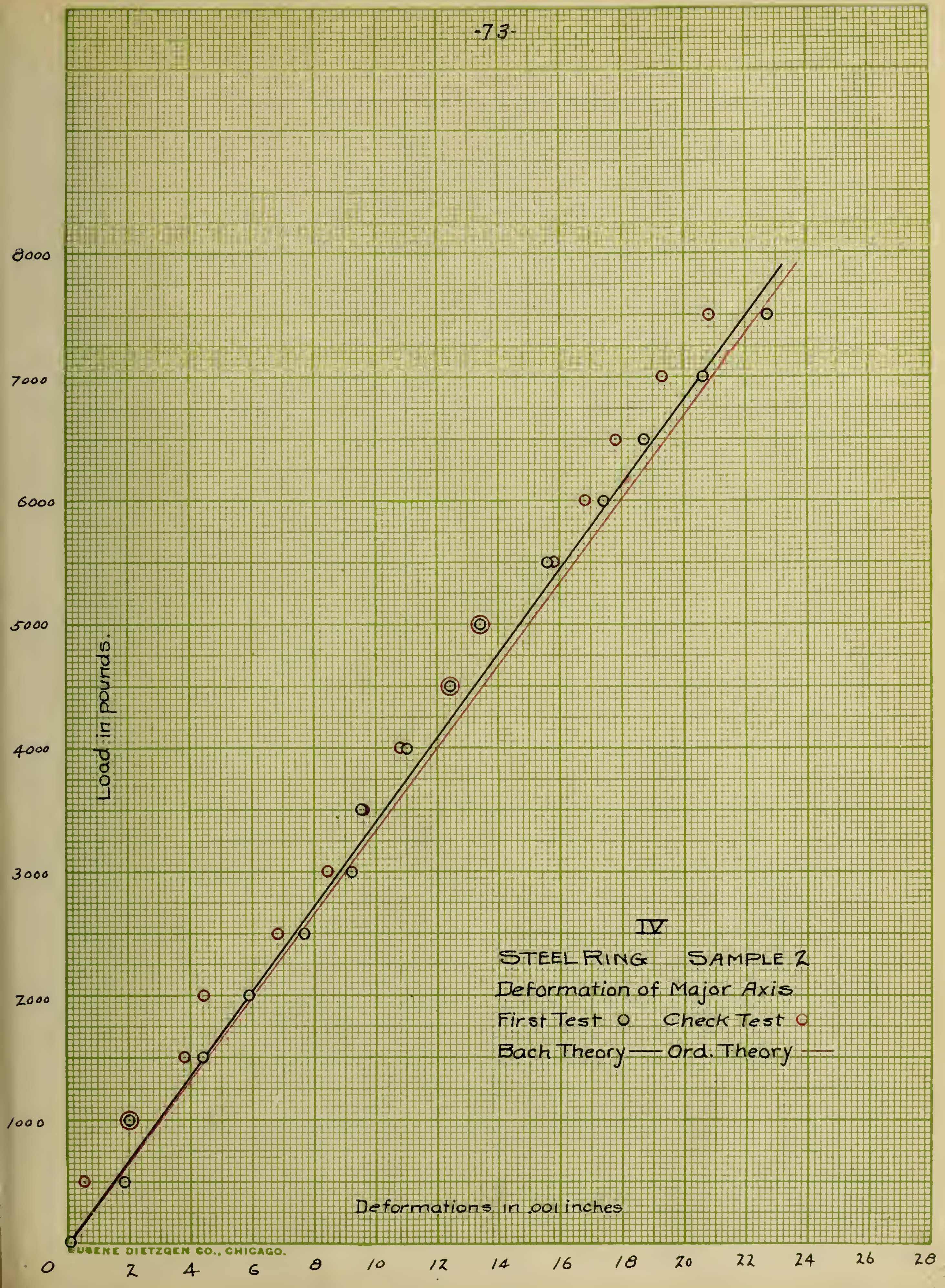

14,000
12,000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Load in pounds
Elongation in .001 inches
I
TEST PIECE SAMPLE 2
Diam - .316" Ring - 12"
Modulus - 26,200,000
Max. Load - 18,000#
Elastic Limit - 28,000#
Elongation - 26%
EUGENE DIETZGEN CO., CHICAGO.

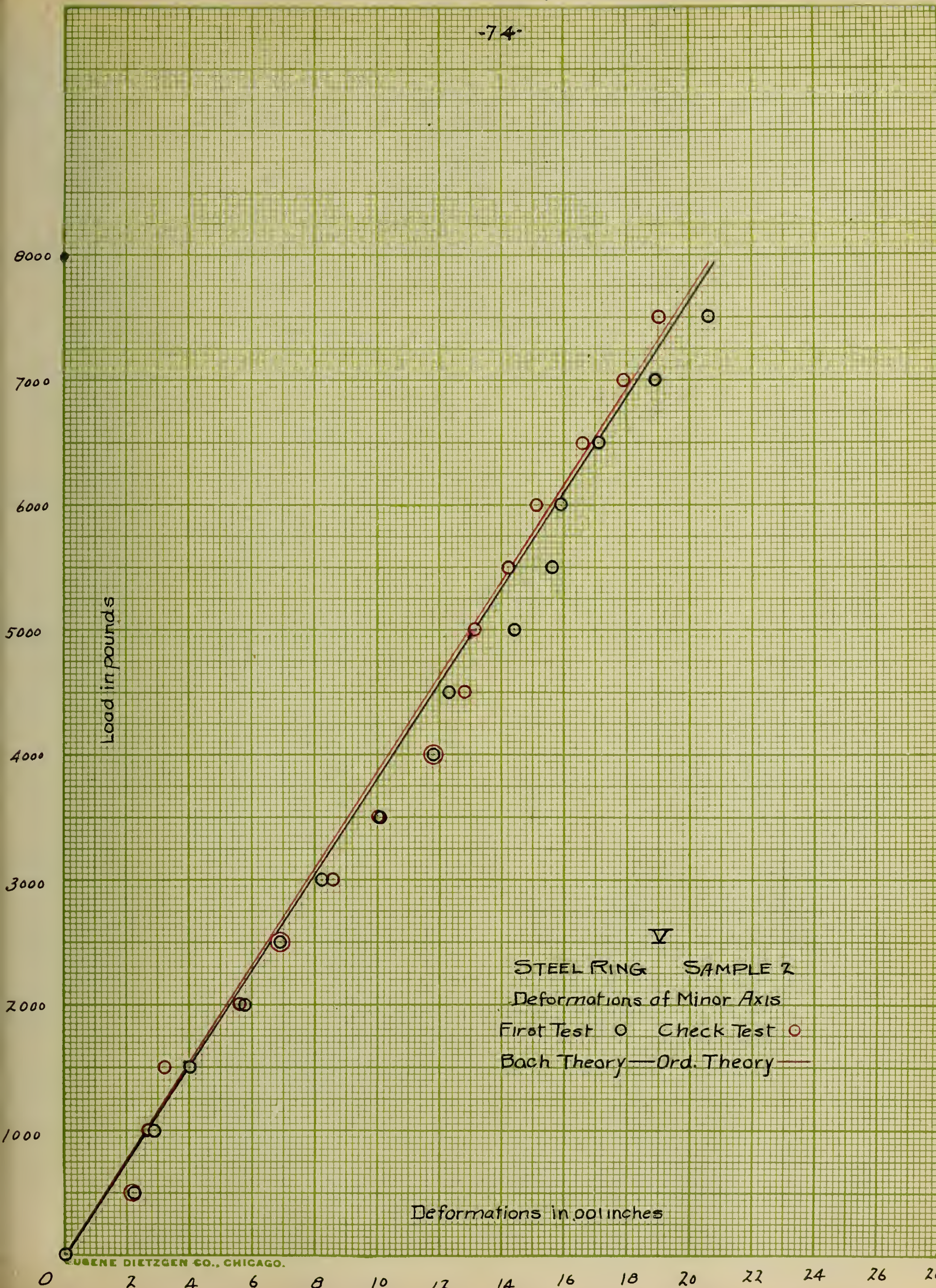


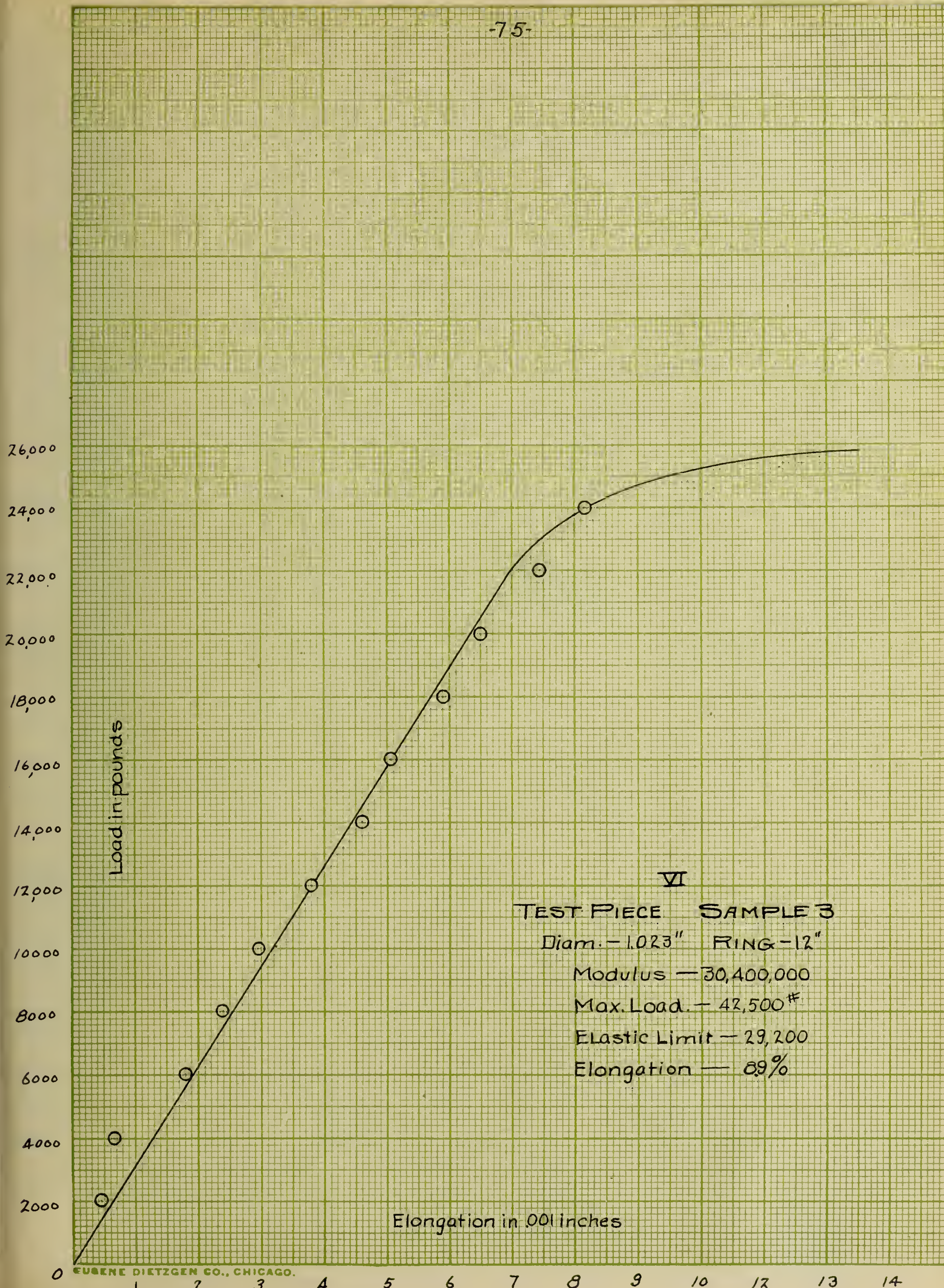
8000
7000
6000
5000
4000
3000
2000
1000
0
Load in lbs
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Deformations in .001"
II
STEEL RING SAMPLE I
Deformations of Major Axis
First Test O Check Test O
Bach Theory —— Ord. Theory ——
EUGENE DIETZGEN CO., CHICAGO.

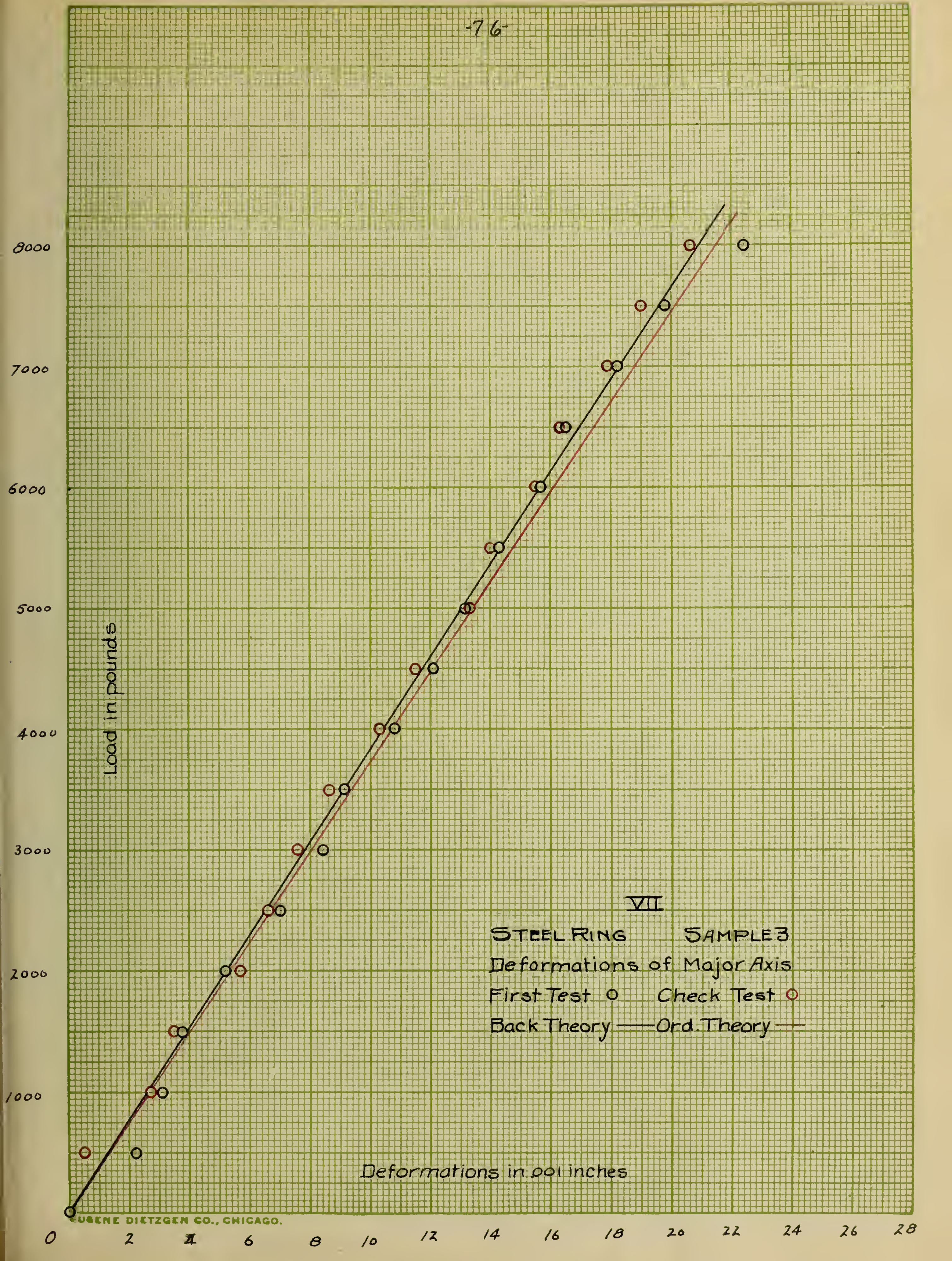


8000
7000
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Load in pounds
Deformations in .0001 inches
III
STEEL RING SAMPLE I
Deformation of Minor Axis
First Test o Chech Test o
Back Theory —— Ord. Theory ——
EUGENE DIETZGEN CO., CHICAGO.

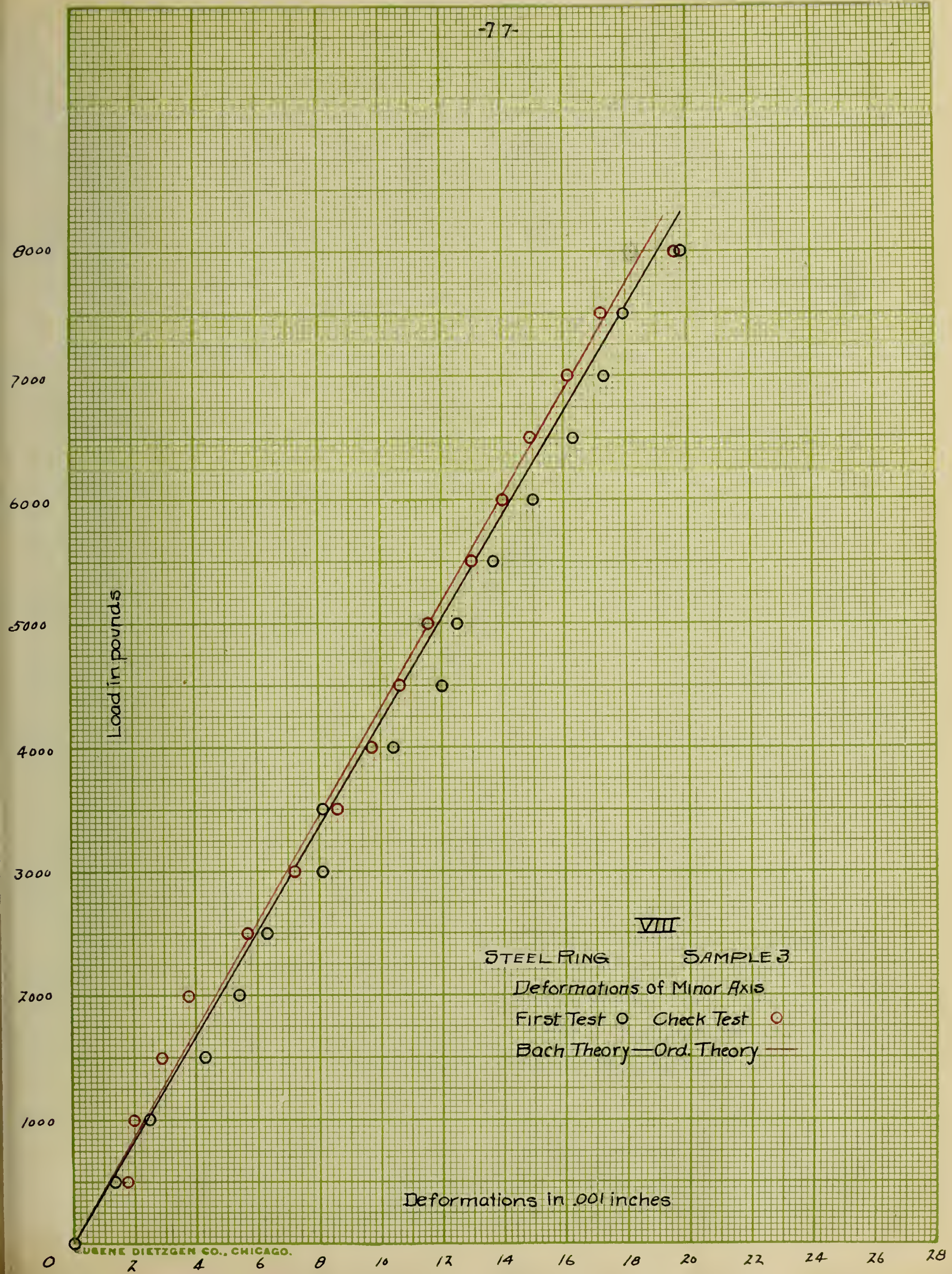

8000
7000
6000
5000
4000
3000
2000
1000
0
Load in pounds.
Deformations in .001 inches
2
4
6
8
10
12
14
16
18
20
22
24
26
28
IV
STEEL RING SAMPLE 2
Deformation of Major Axis
First Test O Check Test O
Bach Theory —— Ord. Theory ——
EUGENE DIETZGEN CO., CHICAGO.

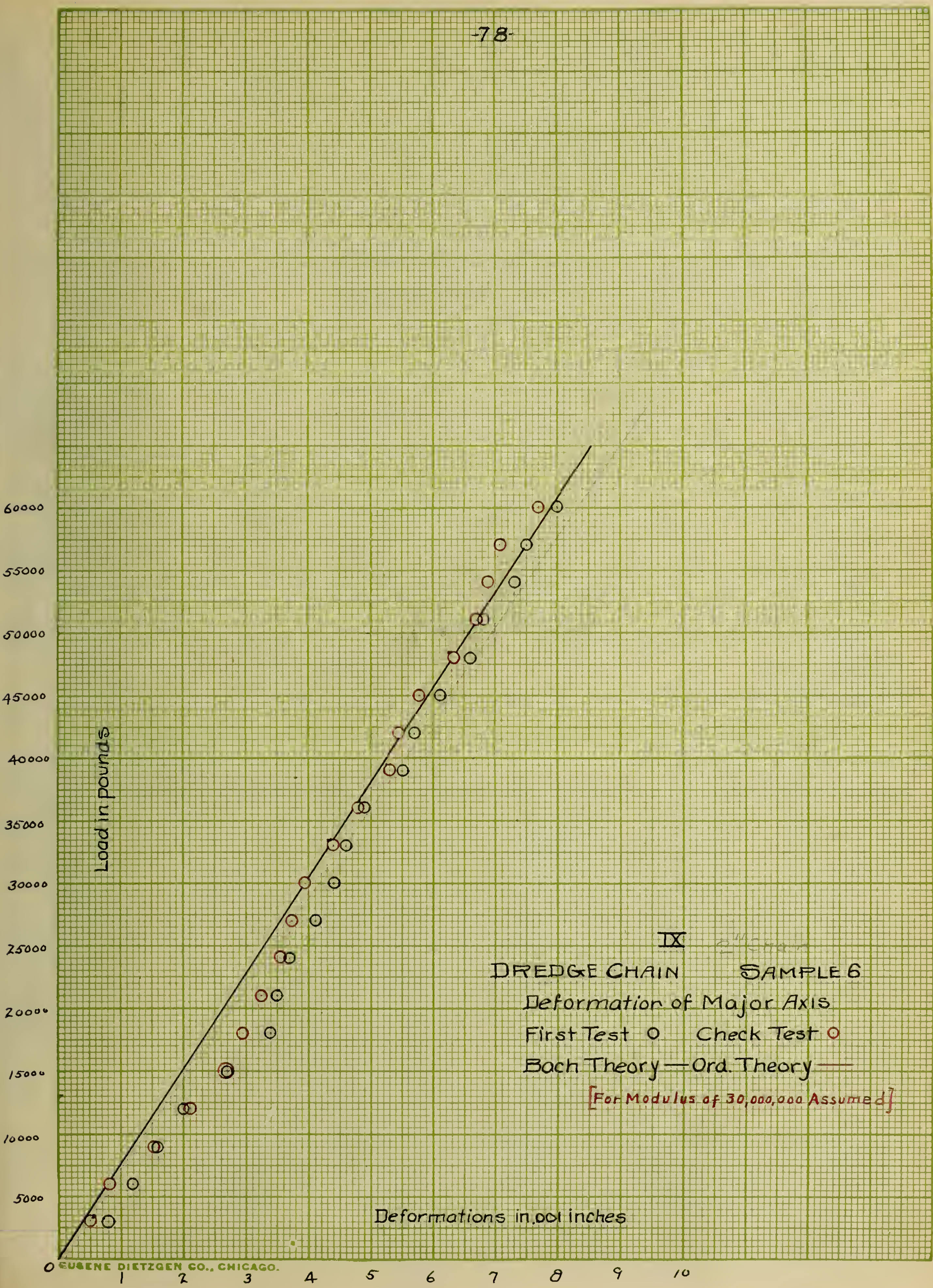

8000
7000
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Load in pounds
Deformations in .001 inches
V
STEEL RING SAMPLE 2
Deformations of Minor Axis
First Test
Check Test
Bach Theory
Ord. Theory
EUGENE DIETZGEN CO., CHICAGO.


26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10000
8000
6000
4000
2000
0
Load in pounds
VI
TEST PIECE SAMPLE 3
Diam. - 1.023" RING - 12"
Modulus - 30,400,000
Max. Load. - 42,500#
Elastic Limit - 29,200
Elongation - 8.9%
Elongation in .001 inches
EUGENE DIETZGEN CO., CHICAGO.
1
2
3
4
5
6
7
8
9
10
12
13
14

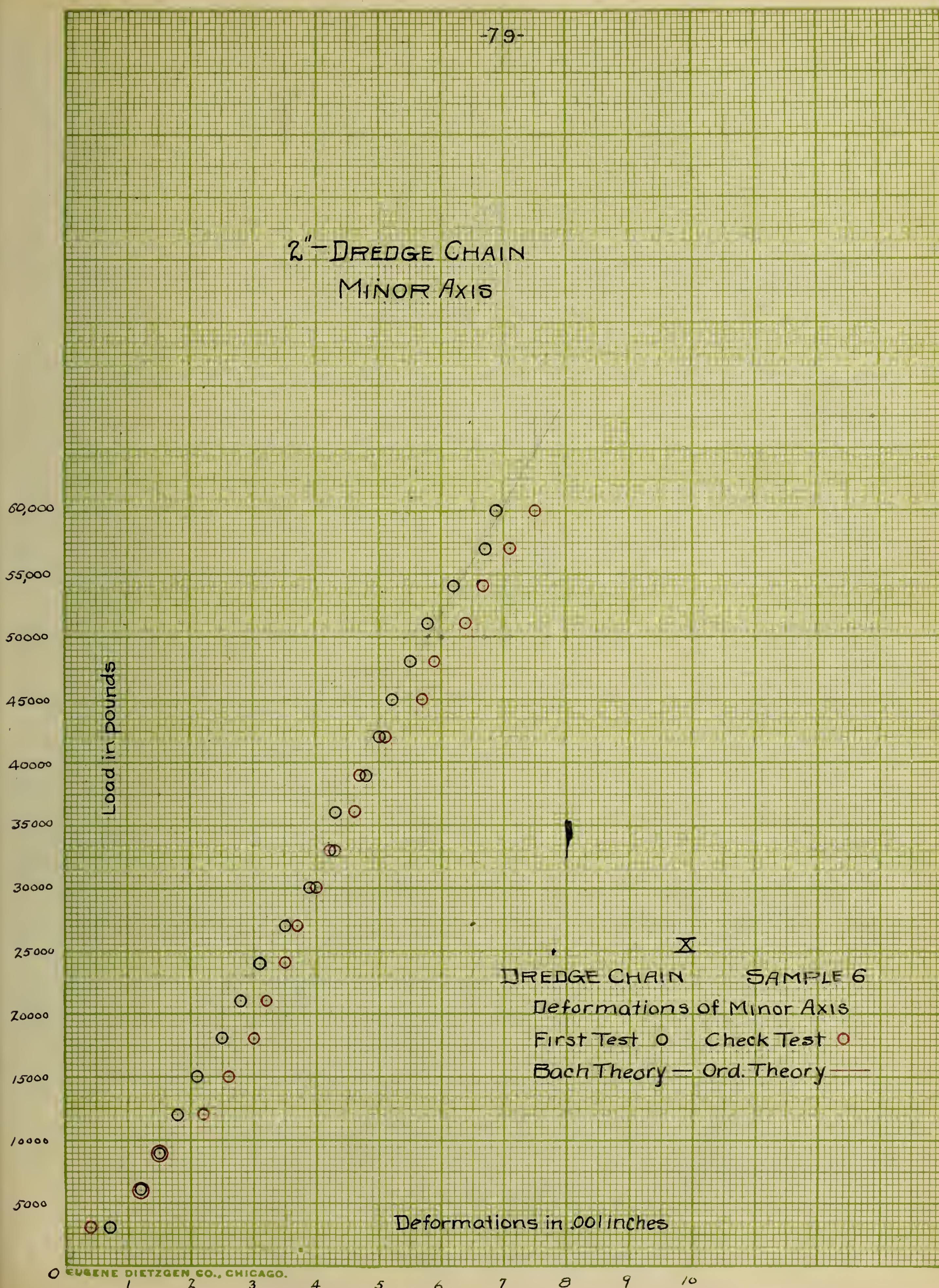


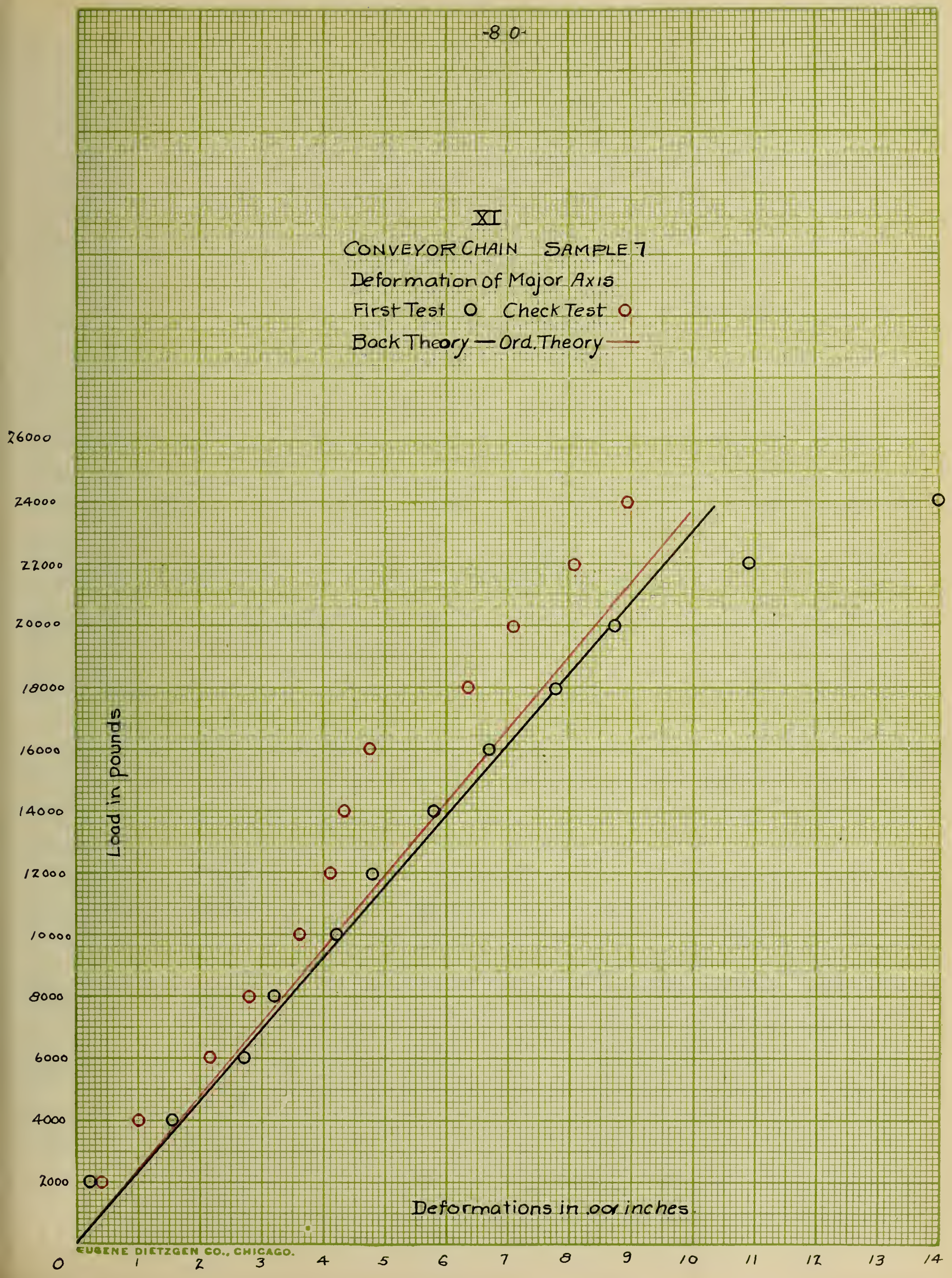
8000
7000
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Load in pounds
Deformations in .001 inches
VII
Steel Ring Sample 3
Deformations of Major Axis
First Test
Check Test
Back Theory
Ord. Theory
EUGENE DIETZGEN CO., CHICAGO.

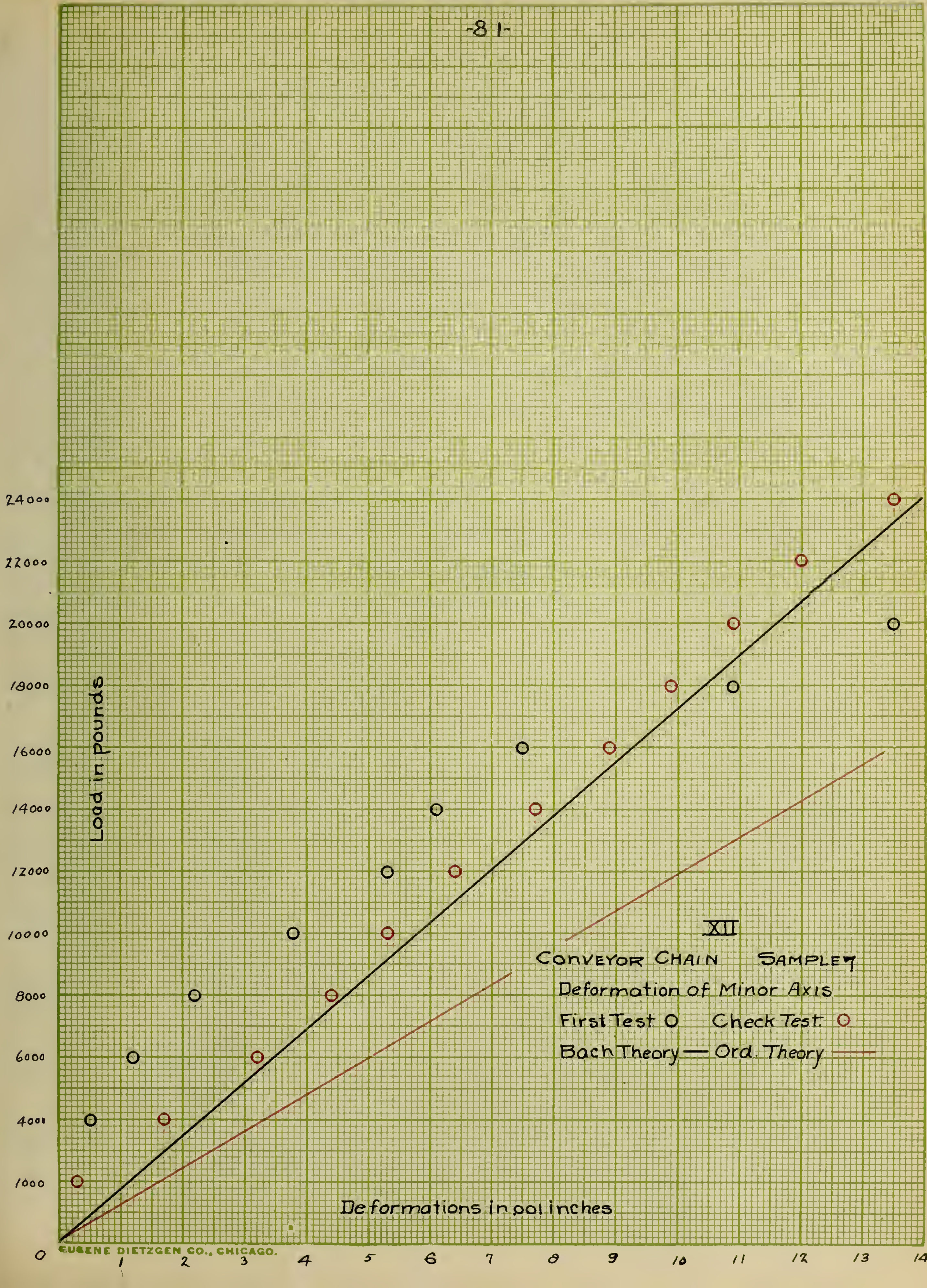

8000
7000
6000
5000
4000
3000
2000
1000
0
Load in pounds
2
4
6
8
10
12
14
16
18
20
22
24
26
28
VIII
STEEL RING SAMPLE 3
Deformations of Minor Axis
First Test ○ Check Test ○
Bach Theory — Ord. Theory —
Deformations in .001 inches
EUGENE DIETZGEN CO., CHICAGO.

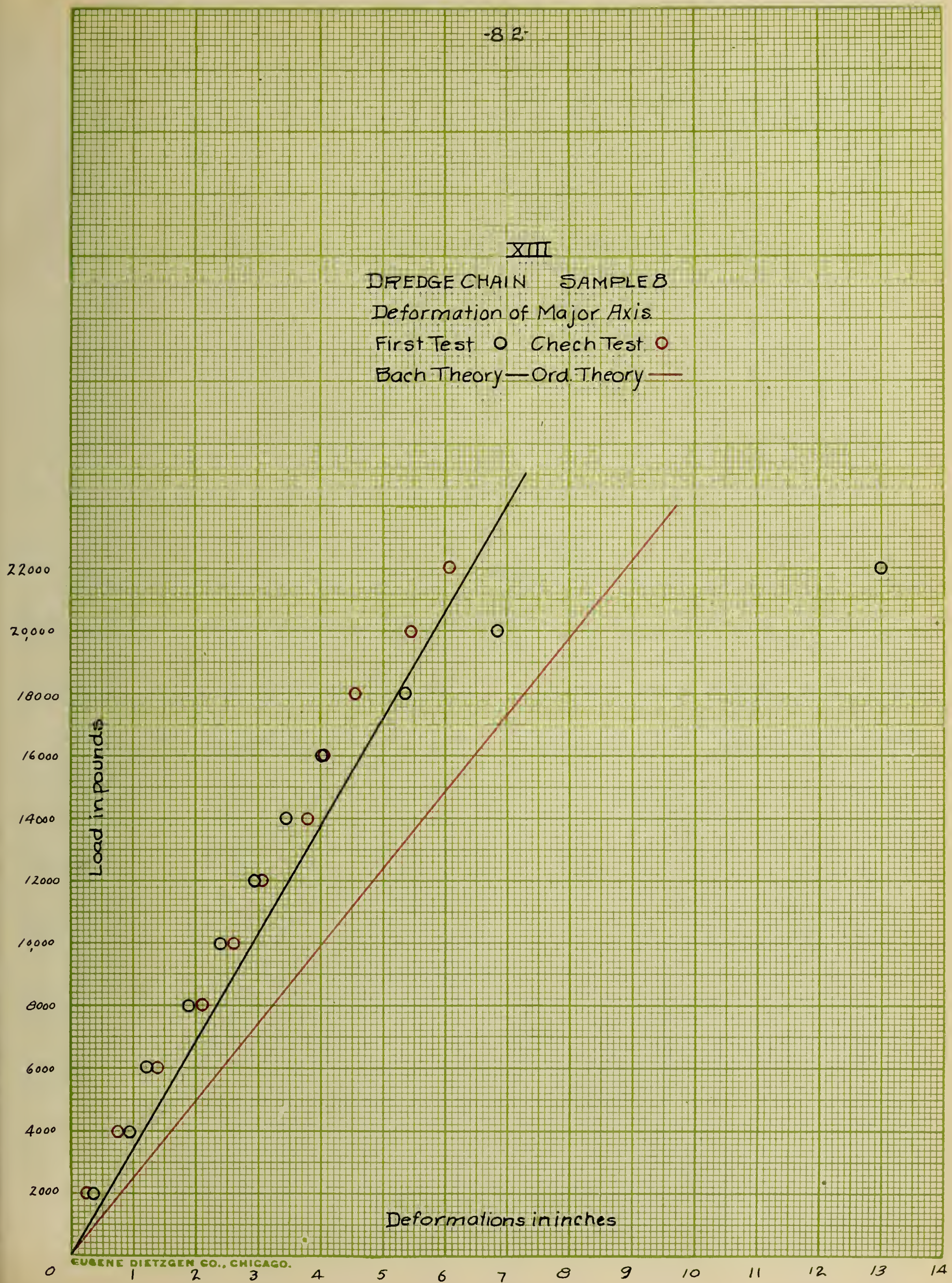


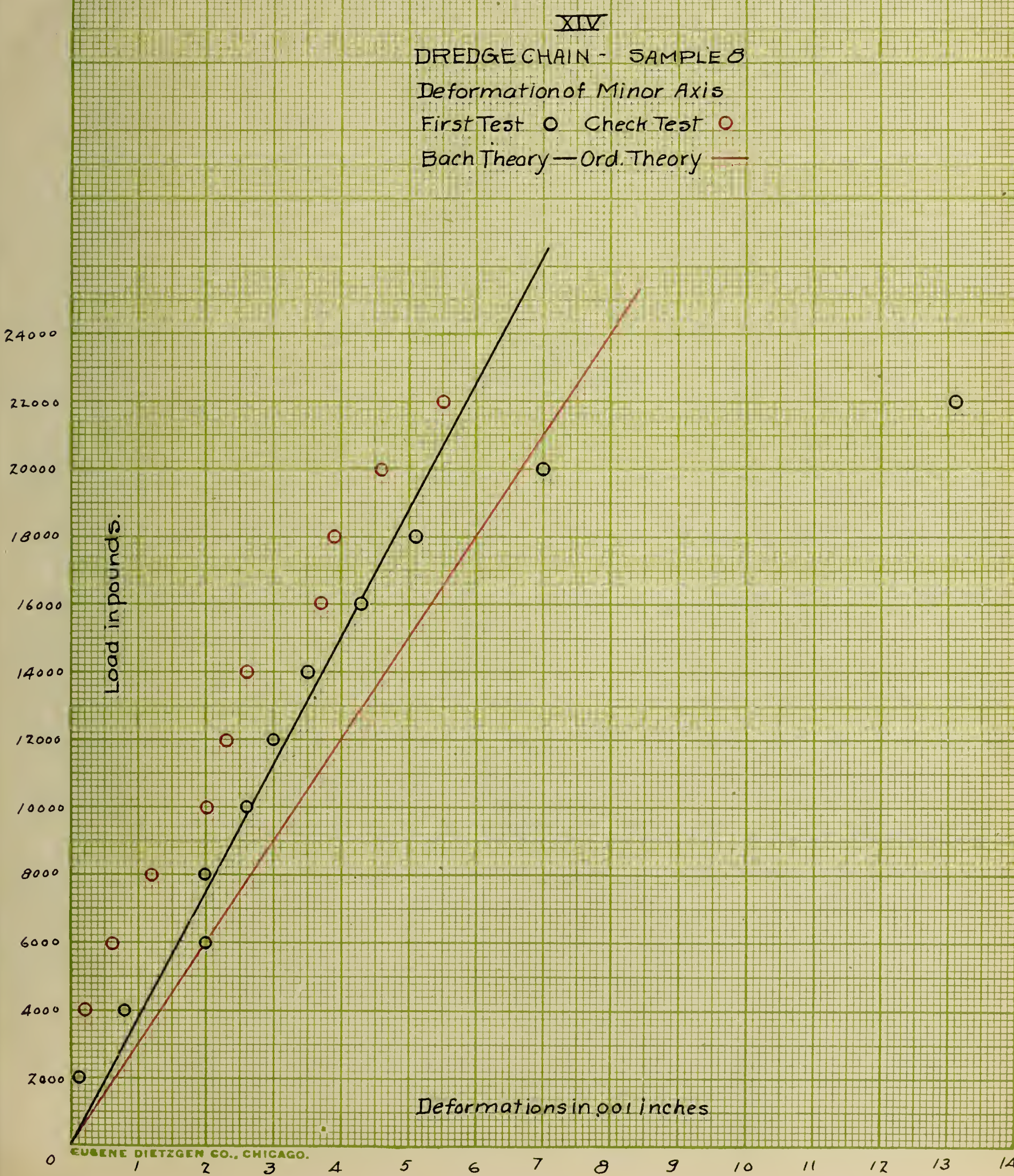
IX
DREDGE CHAIN SAMPLE 6
Deformation of Major Axis
First Test ○ Check Test ○
Bach Theory — Ord. Theory —
[For Modulus of 30,000,000 Assumed]
Load in pounds
Deformations in .001 inches
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1
2
3
4
5
6
7
8
9
10
EUGENE DIETZGEN CO., CHICAGO.


2"-DREDGE CHAIN
MINOR AXIS
60,000
55,000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Load in pounds
1
2
3
4
5
6
7
8
9
10
Deformations in .001 inches
X
DREDGE CHAIN SAMPLE 6
Deformations of Minor Axis
First Test O Check Test O
Bach Theory — Ord. Theory —
EUGENE DIETZGEN CO., CHICAGO.


XI
CONVEYOR CHAIN SAMPLE 7
Deformation of Major Axis
First Test O Check Test O
Bock Theory — Ord. Theory —
Load in pounds
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Deformations in .001 inches
EUGENE DIETZGEN CO., CHICAGO.


24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Load in pounds
Deformations in .001 inches
XII
Conveyor Chain Sample 7
Deformation of Minor Axis
First Test O Check Test O
Bach Theory — Ord. Theory —
Eugene Dietzgen Co., Chicago.


XIII
DREDGE CHAIN SAMPLE 8
Deformation of Major Axis
First Test O Chech Test O
Bach Theory — Ord. Theory —
Load in pounds
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Deformations in inches
EUGENE DIETZGEN CO., CHICAGO.


XIV
DREDGE CHAIN - SAMPLE 8
Deformation of Minor Axis
First Test O Check Test O
Bach Theory — Ord. Theory —
Load in pounds.
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Deformations in .001 inches
1
2
3
4
5
6
7
8
9
10
11
12
13
14
EUGENE DIETZGEN CO., CHICAGO.